VOLUME XXXIV NUMBER 3

BOTANICAL GAZETTE

SEPTEMBER, 1902

THE RISE OF THE TRANSPIRATION STREAM: AN HISTORICAL AND CRITICAL DISCUSSION.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXXVIII.

EDWIN BINGHAM COPELAND.

(WITH ONE FIGURE)

1. "Le phenomène de l'ascension de la sève est resté jusqu' à nos jours sans aucune explication plausible," wrote Dutrochet in 1837. Knight had said the same thing in 1801. During the intervening century there have been a considerable number of explanations, plausible enough to satisfy their authors, and a very few which have commanded a wide but temporary adherence. Every theory proposed has been overthrown by direct experiment, or shown to be in conflict with generally accepted principles of physics.

The work of Dixon and Joly and of Askenasy during the past decade has extended the knowledge already possessed in physics as to the cohesive power of water, and by the application of this knowledge these authors have developed a theory which has since almost monopolized the field. Believing that the true solution was to be found in this direction, I set up an apparatus intended to illustrate its application more strikingly than had been done before. This artificial tree had so much in its behavior in common with real trees that when all was done I was likewise unable to explain it.

Thirty-one pieces of glass tubing, each 3^{mm} in diameter and

about 40^{cm} long, were filled with plaster of Paris. As the plaster began to set they were put in a dish of boiled water. They were then boiled, cooled, and boiled again, boiled hard altogether two hours, and left in the same water over night. Air could be located by reflection between the plaster and the glass, as isolated bubbles, making on an average probably one-fifth to one-fourth of the area; the amount of air remaining in this way varied in different tubes. These tubes were connected with heavy rubber tubing; this was done by filling the rubber connections with fresh plaster paste and immediately forcing this out with the pieces of glass tubing to be connected. A continuous tube of plaster of Paris was thus made 12.4^{m} in height, reaching up the well surrounded by three flights of stairs in the Hull Botanical Laboratory. Four meters below the top was a T tube full of plaster, whose free arm was closed. The lower end was connected with a U tube full of water and mercury in equilibrium; this represented the root. At the top, above another T tube full of plaster with the free arm closed, was the leaf—a sort of inverted osmometer made by filling a funnel with plaster containing some K_4FeCN_6, tieing over it four sheets of parchment paper soaked in K_4FeCN_6, sealing a glass wall around this, and filling the cup thus formed with a concentrated solution of $CuSO_4$ and NaCl. The surface of liquid exposed was great enough so that in the dry, warm air in the hall evaporation was more rapid than the loss was supplied, so that after the first day there was a slow precipitation, and after several days more water had to be added to forestall drying.

The experiment was started at 3:18 P. M., January 14. I recorded with very numerous measurements the rise of mercury in the closed arm of the U tube, most of which measurements it would be a waste of space to publish. The rise was without break or considerable irregularity. It was:

Until January 14, 4:18 P. M., 3.0^{mm}
Until January 15, 3:18 P. M., 64.5
Until January 16, 3:18 P. M., 101.5
Until January 17, 3:18 P. M., 128.0^{mm}
Until January 18, 3:18 P. M., 150.5

To obtain the decrease in tension in this manometer these

figures must of course be doubled, the suction developed during five days being then 301^{mm}.

From the very beginning of the absorption of water from the U tube this was a successful demonstration that a column of water above 10^{m} high in a porous substance, even in the presence of free air, will not break under its own weight. In addition to this it was very soon evident from the lifting of the mercury that maintaining its continuity did not strain it to near the breaking point. With the removal of water from the tube and the elevation of the mercury at its lower end, the tension of the air in the tube of course diminished and the bubbles expanded. During these five days, however, the expansion was not sufficient to cause any general confluence of the bubbles, even in the upper end of the tube.

At 3:18 P. M., January 18, the leaf was removed and the upper end of the tube closed tightly. The height of the mercury thereafter was:

January 18, 4:18 P. M., 151.5^{mm}	January 19, 11:30 A. M., 155.5^{mm}
January 18, 9:10 P. M., 155.0	January 19, 3:18 P. M., 157.0

The cause of this rise must be sought in the elasticity of the air in the tube. By virtue of this elasticity the suction of the leaf is—to employ materialization as a figure of speech—stored up, and only gradually transmitted to the root. Expressed in terms used with natural trees, transpiration and absorption are not necessarily parallel. This stored up suction is probably represented purely by the rise of 5^{mm} before January 19, 11:30 A. M. The subsequent more rapid rise I ascribe to the fact that the temperature of the hall fell very decidedly that afternoon. Such an effect of cooling, and the opposite result of warming, appeared at some other times.

That the tube could take up more water if the pressure—one atmosphere *minus* 314^{mm} of mercury—at the bottom were increased was evident; still, I thought it worth demonstrating. To this end mercury was poured into the free arm of the U tube until it stood even in both arms. At the same time the T tube 4^{m} from the top was opened and connected with a capillary

tube 1 m long full of water, whose lower end was in a mercury bath. This was done at 3.40 P. M., January 19. The height of the mercury was:

At the bottom	4m from the top
January 19, 7:20 P. M., 9.0mm	450mm
January 20, 9:50 P. M., 28.5	530

The suction at the bottom was then 57 mm. At 1 P. M. the connection at 4 m had sprung a leak. It was unfair to compare tubes of such different caliber, so the U tube was replaced by a capillary of the same bore as the other, as nearly as possible, and arranged like it. Starting at 1:15 P. M., January 20, the height of the mercury was:

At the bottom	4m from the top
January 20, 3:45 P. M., 130mm	455mm
6:25 P. M., 186	494
9:10 P. M., 252	531
January 21, 10:30 A. M., 326	550

On January 23 at 10:30 A. M., bubbles having twice been removed from the connection, the mercury at the bottom reached 428mm.

The experiments continued about two months, during which I took several pages of measurements. At one time I arranged the osmometer so as to record the volume of water it absorbed, and found again that for a limited time it could be withdrawn from the tube very much faster than it was taken up lower down. I tried to determine the difference in the suction at the three openings in the tube when the mercury should be drawn up at each until they were in equilibrium; but this was reached so slowly that if there was no other accident, air always came out of the main tube and interfered. During the whole time that the experiment lasted there was a gradual increase in the air in the tube, and with this a decrease in the difference in tension at different heights.

The experiment ended with closing the T tube connections and setting the root end in a solution of eosin. As the eosin rose slowly in the tube, it was very easy to see that it left air between the plaster and the glass; rather more air than was

there when the apparatus was set up, but still so little that it was in small isolated flat bubbles.

While no experiment with any kind of an artificial tube can have the force of a demonstration as to what occurs in a real tree, the behavior of this apparatus was like that in trees as we know it, not only in the general achievement of the elevation of water to a still undefined height, but also in enough known details to make it most probable that the same fundamental physical principles are operative in both cases. But as already said, an analysis showing the elementary factors by which the water is raised has baffled me, even in my own apparatus.

The motive idea in setting up the apparatus—that the cohesion of the water in the tube must be responsible for any suction exerted more than 10^m below the top—was certainly a mistake. This is shown by the readings of the manometers higher up, and also by the continued rise of the mercury at the bottom, after suction at the top ceased, January 18. Both of these observations indicate that the suction developed in the tube is not as great as one atmosphere; that a difference in pressure of less than one atmosphere between top and bottom will lift water much more than 10^m under the peculiar conditions here present. But how? It might be that when water is drawn from the top of the tube it rarefies the air there, and that the suction so arising is propagated downward as largely as possible by the air, and that the bubbles and as little water as possible separating them are thus put in motion. In this way the suction necessary to lift the water should be only equal to that of a column of water equal to the total height of the indices separating the bubbles. But I did not observe that the bubbles moved, and my doubt as to their doing so is very much strengthened by the final observation that the rise of the eosin solution did not drive all the air before it. The tube did become more full of air in the upper part; but I think this was chiefly due to greater suction there, this causing the air present to occupy more space, and hastening diffusion inward through the rubber connections; and two of the "leaves" used leaked. It may be taken

as a fact that in wood there is no general upward movement of free air. Therefore, if it is believed that the behavior of this tube depends on the movement of the bubbles, the experiment is not appropriate to the problem. I shall show that the cohesion explanation is open to exactly the same objections in nature which disqualify it in this tube. This leaves a true explanation to be sought outside of the cohesion of the water, or the rise of the bubbles; by analogy this is probably true in my experiment.

The missing link in the problem is some play of surface tension. Assuming for the moment that the suction is transmitted largely by the air and that the bubbles are carried upward, there is still present continuous water in the plaster, and the upper end of this column would then be subject to the pull of its own 12^m of water, *plus* the suction at the bottom. Its surface tension —which I would rather call capillarity than cohesion here— might enable it to endure this strain. As a matter of fact, though, the tension of the water in the plaster and that of the air and the water around it at the same height must be practically the same. And since the surface tension opposes the movement of the bubbles, but not that of the water, it is natural that the latter should move when either must.

Any further discussion here would be duplicated in sifting the theories on the ascent of sap in nature. The positive result of our experiment is that the water column being continuous, but air being present, a suction of less than one atmosphere can still operate as a suction more than 12^m lower down.

There is an immense mass of published experimentation on the rise of the transpiration stream, whose results are not doubted. During the last four years I have repeated a large part of it for the sake of first-hand familiarity. I shall not add to the literature by republishing work already unquestioned.

II. Dutrochet, in the work quoted in the introduction, says that two forces cooperate to raise the sap: one of repulsion, osmotic in its nature, in the roots; and one of attraction, which is also osmosis — Dutrochet calls it endosmosis — in the leaves.

The driving force in the ascent of sap is root pressure. Seve-

ral explanations of its mechanism are conceivable. A suggestion by Pfeffer, that an unequal distribution within the cell of its osmotically active matter could cause a stream through the cell, has sometimes been adopted as the best solution. But to maintain this inequality would use as much, or rather more, energy than is required to keep up the osmotic pressure present and to lift the water however far it is forced; and this energy would presumably be a net loss to the plant. Detmer (1877) and C. Kraus regarded root pressure as a function of tissue tensions; but the tensions to be observed do not justify this view; and if they did, the solution would not be ultimate, for how should the tissue tensions arise and be maintained? Under the most advantageous conditions external to the active cells, a rhythmic variation in their permeability would result in a root pressure corresponding to the loss of osmotically active matter. But this would make an exceedingly poor machine, unless, as in the original scheme of this kind, by Godlewski, an unequal distribution of the permeability works with the periodic variation. And unequal permeability of different sides of the cell constitutes a perfectly sufficient explanation without any periodicity.

The greatest pressure must be exerted on the side of the cell where resistance to the passage of the solute is greatest. By virtue of this greater pressure when the cell can contain no more water, water will be taken up there, and given off on the other, more permeable side, with at least as much of the solute as would exert an osmotic pressure equal to that under which the water escapes. Artificial cells illustrating this mechanism have been constructed by Sachs (1882) and myself (1900).[1] In so far as its diffusion out of the tracheae into the cortex is resisted, the matter dissolved in the sap in the tracheae exerts an osmotic pressure against the surrounding cells, and to that extent a root pressure can then be maintained without any subsequent loss of solutes by the living cells. It seems probable to me that this suggestion represents the mechanism of the bleeding

[1] Hofmeister's artificial cell (1858: 11; 1862: 145), sometimes refered to as illustrating this action, had all its membranes alike.

of trees in spring better than does the preceding one. The two are closely related, and it would be difficult to distinguish them by experiment. Both have the source of energy in the concentration of the sap. Either provides for only a limited period of high pressure, while the supply of stored, dissolved, or soluble material in the root is carried away by the sap. In its essential features this explanation of the mechanism of root pressure was offered by Brücke in 1844. He illustrated (pp. 194–6) the proportionality of the concentration of the sap to the pressure observed, and said: "Wir werden in der Folge in einer andern Abhandlung näher betrachten, wie sich die Zellen vermittelst dieser löslichen und aufquellenden Substanzen zuerst strotzend mit Wasser anfüllen, und wie dann, in dem sie immer noch mehr Wasser anziehen, das was sie in ihrer Höhle nicht mehr beherbergen können, mit einem Theile der gelösten Substanzen als Saft in die benachbarten Spiralröhren hineingepresst wird." I cannot find that the treatise promised here ever appeared.

The parallel between pressure and concentration is illustrated again by the well-known use of the sap of birch and maple, trees with high root pressure, as sources of sugar. Clark (1874:188) found a root pressure in a *Betula lenta* seventy feet high sufficient to lift water 84.77 feet, the pressure in a root being higher yet. *Acer saccharinum*, with 3.57 per cent. sugar in its sap, registered a pressure of 31.73 feet of water. Clark also reports a pressure of 49.52 feet—6.5 feet above Hale's figure—by grape, the sap being sweet to the taste. The curve given by Schröder (1865) for the concentration of the sap of birch during the season and Clark's for the pressure are parallel, though the inorganic solute decreases constantly. The same author (Schröder, 1869:280) finds 3.44 per cent. sugar in the sap of *Acer platanoides*. The bleeding sap of walnut contains 4 per cent. sugar (Hartig, 1862:88). In all bleeding trees the concentration of the sap and the pressure are supposed to decrease together. In the herbs also (Ulbricht) the concentration of the sap decreases as bleeding goes on. Almost all publications on the concentration of the sap are in such terms that it is impossible to compute the

osmotic strength with any approach to exactness, but they still indicate that it is far more than sufficient to account for the accompanying pressure. On the other side is a statement by Duchartre (1859) that the water guttated by Colocasia is almost like distilled. The analysis was by Berthelot, who found traces of KCl, $CaCO_3$, and organic matter. The earlier statement by Schmidt, who does not seem to have evaporated the water, that the guttated fluid is chemically pure water, is discordant with all modern results. Unger (1858) found 0.056 per cent. of solid matter in it. For other literature see Burgerstein (1889:405). To account osmotically for this guttation the water would have to be more concentrated than that absorbed by the roots by perhaps 0.03 per cent. of KCl.

According to Strasburger (1891:851), "Belegzellen" are rich in content during the time of bleeding, but not afterward. Still, Strasburger doubts their passing this content into the tracheae, and so setting up a root pressure; but his reason against this seems to be chiefly *a priori*, and based on the unsound assumption that the cells would be obliged to lose the sap in the same concentration in which they hold it.

In herbs, especially in young seedlings, it is very common to find bleeding or guttation during only a part of each day. The same plants in which guttated drops are found in the morning are likely to contain air under a decidedly diminished pressure in the afternoon. The reason is that the roots cannot furnish water as rapidly as it evaporates. But it is also possible that the activity of the roots is less by day, the removal of the hydrostatic pressure in the tracheae stimulating the active cells to become less permeable to their solutes on that side, and so economize their contents when it would be useless to let it escape. Labillardière, according to various text-books, says the palm *Arenga saccharifera* bleeds a sap richer in sugar by night than by day. The daily periodicity in pressure occurs also in trees. The bleeding of Carpinus (Strasburger, 1891:841) begins during the night and ceases before noon. Birches may also cease to bleed before noon (Detmer, 1887), but may con-

tinue until after 2:00 P. M., even on bright days, as I have observed in *B. lenta*. Ernst (1876:35) tells of water guttated by *Calliandra Saman* falling like a fine rain all day.

Root pressure rises rapidly with the temperature of the ground. The bubbles of air in the tracheae enlarge when warm, and, as Sachs points out (1860; Hofmeister, 1862), this will force water upward and may well work with real root pressure in the spring bleeding of grape, maple, etc. I would hesitate to ascribe so much importance to it, however, as does Strasburger (1891:833 *seq.*). If bleeding were very largely due to it the daily periodicity would be reversed, as sometimes occurs, especially near the close of the bleeding season (Hartig, 1863:277; Clark, *l. c.*).

According to Wieler (1893:63) guttation is dependent on the presence of free oxygen. Wieler construes this as an argument that root pressure is caused by differences in concentration maintained within the cell. But Purjewitsch's (1897)[2] discovery of the great influence of oxygen on diffusion through the protoplasm converts Wieler's point into a better one for the otherwise more plausible theory that root pressure depends on permeability to the solute.

The minor rôle played by root pressure in the ascent of sap is obvious from the limited work possible by any pressure to be observed, and from the fact that it is altogether absent at the times during the season when transpiration is most active. On the latter point enough has been said. As to the pressures, those which I have cited are the highest ever recorded, with the best subjects growing in our climate. With ordinary subjects which show any root pressure at all it is usually only a few centimeters, or only millimeters, of mercury. It is true that the pressure as measured by manometers is an excess over the counter pressure of the atmosphere. Root pressure unable to overcome this can be demonstrated in many plants (Scheit, 1886:701; Wieler, 1893:97 *seq.*) if the atmospheric pressure is

[2]From instances in which the food normally diffuses from the cell without apparent change, I am unable to agree with Purjewitsch in ascribing the effect of the presence or absence of oxygen to its action on enzymes.

removed; but in living cells, when the gas higher up in the stem is not more dilute than that outside, it must exert a similar resistance of at least an atmosphere to the rising sap. In the spring when root pressure is most active, manometers inserted at different heights show pressures corresponding to columns of water of the same differences in height (Clark; Hofmeister, Flora, 1858: 4.) So water in the tree, when it practically fills the lumina, will at most be shoved up as far as the same pressure would drive it in a glass tube. As we will see later, this is not necessarily the case when the wood contains a great deal of rarefied air.

III. Let us now turn to the force of attraction. It is a matter of common understanding that the leaves have available practically unlimited energy for the elevation of water if only it can be so applied. Of the radiant energy absorbed by the chlorophyll but a small fraction is used in photosynthesis; and evaporation, by cooling the leaf, enables it to absorb more heat from the air. This energy is nearly all used for evaporation. Whether we say with Mayer (1895 : 366) that the cause of evaporation is "die lebendige Kraft der Wassermoleküle durch welche diese geneigt sind Dampfform anzunehmen," or with Nägeli (1860 : 38) that the energy is drawn from the tissue itself, it ultimately comes as heat and light from without. Whatever force has been used in drawing water up to the leaves must be overcome when it has evaporated; which slightly decreases the amount evaporated. At the same time, the same force becomes available for the elevation of more water. The energy thus indirectly used in lifting is relatively inconsiderable. In a former note (1900), figuring the latent heat of evaporation, which varies with the temperature, at 536 calories, the mechanical equivalent of a calorie being 424, I pointed out that the energy used in vaporizing water would lift it about 142 miles. At ordinary temperatures the latent heat of vaporization is enough greater to raise this to perhaps 156 miles. Of course, no large part of this could be used in lifting (Rodewald, 1892). Nägeli (1860 : 39) says that the evaporation uses in general 131

times as much energy as assimilation, which in turn uses eighty times as much as it takes to lift the water; obviously this depends upon how far this is lifted.

It must be almost exclusively true in nature, as Askenasy (1895 : 333) has it in his very clear and concise scheme of the energy changes in the rise of water, that the chief force in the leaf which removes the sap from the tracheae and in spite of which it evaporates, is osmosis. To be complete, it may be said that imbibition intervenes between osmosis and evaporation to get the sap through the wall of the mesophyll cells from which most of it evaporates. On the other side, it also intervenes in the walls between the living contents of the mesophyll and the tracheae from which they draw water. Very likely a little water passes out in the walls from the vessels to the point of evaporation independently of osmosis; at any rate this is not prevented by suberization of the anticlinal walls, as in the endodermis of roots. When water evaporates from a mesophyll cell, the concentration of its sap increases and the tension of its wall is eliminated. In both of these ways, but at first in chief part in the second way, the cell is enabled to draw more water from whence it can, from the tracheae. Mechanically this elimination of the tension of the wall suggests the elasticity of the wall by which Böhm (1864) at first sought to explain suction by leaves; but the actual tension always remains a stretching. In some of his latest work (1890, etc.) the same author denied the play of osmosis on the ground that transpiration is not stopped by death. Evaporation does occur after death, evaporation of the water in the leaves, and of as much more water as can be drawn up before enough air diffuses into the walls and lumina of the tracheae to close them to water; in leaves of firm texture, especially in evergreens, this does not soon occur. But this is not ground for doubting that in living leaves the water passes through the cells, necessarily, by osmosis.

All water passes from the tracheae by imbibition, and so far as the mechanism of movement in the tracheae is concerned, it matters not whether or not osmosis is active in the leaves (Ask-

enasy, 1895; Dixon, 1896; Darwin, in Darwin, etc., 1896: 336–7; Joly, *ibid.* 649). Regarded purely as a transpiring machine, the live leaf is superior to the dead one chiefly because it does not incapacitate itself by drying. Dixon's suggestion (1896, I) is a good one, that dead leaves transpire less than fresh live ones because the collapse of their cells closes the intercellular space. But his other idea, that the fact that flaccid live leaves evaporate only half as much water as dead ones is due to their loss of "turgescence," seems to me to rest on a confusion of the osmotic pressure of the solutes in the cell sap — which I have tried (Annals of Botany, June 1902) to distinguish as "turgor" — and the state of "turgescence" caused by the "turgor" when enough water is available. It is by virtue of its "turgor" that the mesophyll absorbs water from the tracheae; and the "turgor" is greater, because when the cell shrinks its sap becomes concentrated, in flaccid than in fresh leaves.

The osmotic pressure in the leaf cells is much more than is used in lifting water. From very numerous tests by plasmolysis I can say that it is in general about equivalent to that of 3.5 per. cent KNO_3. In some plants it is much higher; for instance, in grasses and in halophytes. In typical spongy parenchyma the turgor cannot be accurately measured. In the bundle sheath it seems usually to be slightly less than in the palisade tissue, but this may be because the tests of the latter is less accurate. It also seems to be on the whole a little higher in trees than in herbs, but this also may be because the cells are usually smaller in trees, making the turgor appear too high. Dixon (1896, II) has undertaken to measure the turgor of leaves by ascertaining the gas pressure sufficient to collapse the cells and force water from them into the tracheae. The method is not a reliable one until we know something about the passage of the gases into solution and their diffusion into the cells. We have no information as to the turgor in the leaves of very high trees, 60 to 150^m in height, but to lift the transpiration stream it need not be higher than that of herbs.

The mesophyll cells supply themselves with water from the

fibrovascular bundles, whose finest ramifications are fine tracheides.

IV. So far, the mechanism of the movement of water is a very simple problem. The difficulty is in the next step, in explaining how suction in the tracheides and vessels of the leaves can be propagated so as to cause an upward movement along the stem, and even from the roots of lofty trees. Summarizing a part of our empirical knowledge may facilitate a subsequent analysis of the theories. The path of the transpiration stream is, speaking for trees, in the younger wood. The number of years' growth of gymnosperms and dicotyledons which share in conducting it is very variable. Beside this radial limit, the stream supplying any particular part of the crown — as a single branch — is also limited tangentially. A well-known experiment by Th. Hartig (1853:313) illustrates this. He bored five holes in a tree, meeting in the axis, and filled the cavities with "holzsaurem Eisen;" the tree was afterward cut forty feet higher up, and the figure of a star, one ray corresponding to each hole found stained. Experiments on the lateral movement of water by overlapping cuts from opposite sides date back to Hale's. As on various other points, the most valuable collection of data is Strasburger's (1891: 595 *seq.*; 1893: 34, 37). Other more notable work on transverse movement is by Darwin and Phillips, Vesque (1883, 1891: 576), Wiesner (1875). A limit to the ease of lateral movement is necessary in order that any store of water can be retained, while other water moves past it from the ground. It is also necessary for the maintenance of any proportion of air and water in the individual channels.

With the exception of a time in spring when the lumen of some trees becomes full of water forced there by root pressure, the tracheae always contain a considerable amount of air. Scheit maintains that the spaces in the lumen not occupied by liquid water are filled with its vapor, and Sachs in his latest work (1892) inclines toward the same view. But before Scheit's time there was abundant proof of the presence of air, including analyses by Böhm (1878), Faivre and Dupré, and others; and more

recently it has been redemonstrated by Schwendener (1886 : 563), Tschapolwitsch, and Strasburger (1891 : 677). The air content of the heart is rather fixed, but that of the sap wood decidedly variable. With only the same class of exceptions as to the presence of air at all, the air in the tracheae is under a lower tension than that of the atmosphere outside. This lower tension is one of the reasons for the presence of air in the gaseous form. The water absorbed by roots is saturated with air under the atmospheric pressure and at ground temperature. In the trunk the water is usually warmed and a part of the pressure is removed, both tending to cause the air to come out of solution. It has not been so easy to tell why there is not more air in the wood. But Noll's recent discovery that there is an active osmotic movement of gas between the wood and the air outside throws an altogether new light on this question. At least for vessels in or near the leaves, Noll shows that this osmosis will be very largely outward. Before this discovery, the only known immediate cause of the diminished tension of the tracheal air, aside from the relatively inconsiderable influence of occasional cooling, was the removal of water from the lumina to replace that evaporated from the leaves.

The less air the tracheae contain, the greater will be the change in its tension with a given variation in the amount of water present. Evidently the proportion of water present gives an approximate, though not an exact measure of the tension of the air. This proportion of water is in all cases least in summer, the maximum being in winter in gymnosperms, and in spring in dicotyledons (Th. Hartig, 1868 ; Geleznow, 1876. R. Hartig, Bot. Zeit. 1883, disputes this). Th. Hartig (*l. c.*, 20) tested the water content of twenty-six kinds of trees, four feet from the ground, before sunrise, and at 2 :00 P. M., and found the loss of water varying from 2 to 38 per cent. G. Kraus' most accurate work on this subject comes to the same conclusions, epitomized by Kraus himself in Sachs' *Pflanzenphysiologie*, second edition p. 601, as follows: "Die Pflanzentheile (Stämme, Blätter, Früchte, Knollen, Knospen) . . . . sind am Tage kleiner, bei Nacht grösser."

"Diese An- und Abschwellung resultirt aus dem periodisch schwankenden Wassergehalt der Theile; dieser ist regelmässig am Tage geringer, in der Nacht höher." "Der ungleiche Wassergehalt der Organe bei Tag und Nacht ist seinerseits das Resultat aus der ungleichen Thätigkeit der Wasser zu- und abführenden Kräfte." We will return later to the tensions associated with the water content. The rarefaction of the gas in the tracheae is often spoken of as causing a negative tension. The physical condition of a gas makes it impossible that it should exert or even transmit a real negative tension. A gas must always press against whatever confines it; when the gas is rarefied the pressure diminishes, but it can never become a suction.

While lateral movement of water in the wood is difficult, its passage lengthwise of the wood is exceedingly easy. This is easily and conclusively shown by what is known as the "Th. Hartig experiment." As an instructive experiment, we owe this to Sachs; but no one experiment can be identified as "Sachs' experiment," so the misnomer can profitably be retained. As a matter of historical interest it may be remarked that the experiment did not originate with Hartig. Boucherie (1841) had made a technical application of it in substantially the same improved form afterward employed by Sachs. And Biot (*cf.* Biot, 1841) preceded Boucherie, but I have not had access to his earlier papers. Hartig showed that when water was forced out of a stick by warming it, gravity could determine the place of its appearance. Sachs' familiar experiment is to soak a stick in water, dry the ends, place a drop on the upper end, and observe that it is absorbed, while a corresponding drop emerges below. Various woods make good subjects for this experiment, those containing vessels allowing the freest movement. As interpreted by Godlewski (1882: 585–7), it shows that the weight of the water held in the wood is sufficient to overcome the resistance to its movement. Schwendener (1886: 579; also Strasburger, 1891: 773) showed that much less than this pressure is required. Strasburger also showed that an excess pressure of only 20 per cent. is required to cause a movement in sticks of

Acacia as rapid as that of the transpiration stream. Too much air in wood hinders or prevents the movement of water, as proven by Boucherie and many of his successors. It is for this reason that shoots cut in air wilt though the cut end be afterwards placed in water; the lesser tension in the tracheae causing those exposed to fill with air at the outside tension. On the other hand, when the vessels are well supplied with water, the removal of part of it facilitates its movement in response to the "attraction" above—according to Dutrochet. It is my belief that in lofty trees it would be impossible for water to be drawn from the root while the tracheae are even approximately full of it; though of course all that is certain or can be demonstrated empirically is that there is a great deal of space occupied by gas when transpiration is rapid.

In a capillary tube filled with a succession of bubbles of air separated by water (Jamin's chain), the resistance to the movement of the entire column of air and water is very considerable (Jamin, Schwendener, and Steinbrinck). While measurements made in glass tubes are not valid for the tracheae (Strasburger, 1891: 815), the movement of the bubbles in the latter is interfered with by the sculpturing of the walls and the remains of the partitions (Kamerling, 1898, I: 978). The result is that a pressure insufficient to move the bubbles will cause a flow of water between the bubbles and the wall.

Vesque (1882; Ann. Sc. Nat. 1883) and Capus observed under the microscope that bubbles did not prevent a current above and below them in the same vessel. Vesque (*cf.* 1891: 384; the original publication was in the *Annales Agronomiques* 11: 1885) afterward determined that this current passed between the bubble and the wall; which was confirmed by Strasburger (1891: 703). Pappenheim (1892: 161) was unable to demonstrate such a movement; nor could Schwendener, who denied its possibility (1886; 1892: 920). I have not found Vesque's experiments exceedingly difficult, either in glass tubes or in tracheae, and will describe some of them briefly later in this paper. The same phenomenon can be conveniently observed in

the rhizoids of the Marchantiaceae. As we are told by Kamerling (1897 : 12), after a bubble is formed in one of the "pegged" rhizoids, it may increase in length downward as well as upward, the water from the lower end flowing past the bubble. Another of Strasburger's experiments (1891 : 819) furnishes as positive proof as that by direct observation; the same experiments which proved that the Jamin's chain was held less firmly in tracheae than in glass showed that a pressure insufficient to move the bubbles would force water through the same tracheae.

V. Some of the theories as to the rise of water, and retaining only an historical interest, may be mentioned very briefly. Knight (1801 : 344) ascribed the ascent of sap to contraction by the medullary rays, "the silver grain," which somewhere touch all the vessels. "Their restless temper, after the tree has ceased to live, inclines me to believe that they are not made to be idle whilst it continues to live." If a tangential surface of wood is exposed during the day, the silver grain appear as minute clefts into which pins may be stuck and be found pinched fast at night. This contraction, he thought, might elevate the water.

Bischoff (1836, Vol. II, pt. 1:238, 271) believed the sap to be driven up, not in the vessels but in the cells, by the contractility of the walls, acting under the influence of the living contents. Böhm at one time (1878) held a similar view, omitting, however, as he always did, any dependence on the activity of the protoplasm. He called the movement (p. 230) "une fonction de l'élasticité des parois cellulaires et de la pression atmosphérique." But already in the same paper (p. 236) he recognized that in cells with rigid walls their elasticity is replaced by that of the air in the lumen.

Th. Hartig (1853), observing facetiously that his was the age of steam, thought the cavities of the pits might act as millions of little engines so numerous that when warmed even a very little they could drive the water up.

The agitation of trees by the wind was plausibly used by Spencer to move water in the vessels from the roots, where it was most abundant, to the twigs and leaves where evaporation

created a constant demand; the arrangement being "a sort of rude force-pump worked by the wind."

Scheit suggested that slight differences in temperature might raise the water "auf dem Wege der Destillation" (1885:477). But, as Scheit himself pointed out, this would not raise any mineral food.

VI. While the imbibition theory has had no champion since the death of Sachs, it reigned too long to be passed over in a sentence now. Granting Sachs' claim that the imbibition theory was his personal intellectual product and property, it would seem but fair to confine ourselves in discussing it to the final stage of its evolution. But it was in one of its earlier forms, afterward outgrown by its great exponent, that the theory was dominant. Sachs lists the publications in which this theory was developed in his hands in his *Vorlesungen über Pflanzenphysiologie* (2d edition, 225). Its period of greatest vogue was about the close of the seventies, after the publication of the paper "Ueber die Porosität des Holzes." The imbibition theory said that the water was carried altogether in the walls of the wood elements, where it was absorbed and held by imbibition. The substance of the wood walls was believed to be very remarkable, in "Dass sie (the walls) verhältnissmässig nur wenig Wasser in sich aufnehmen, dass dieses wenige Imbibitionswasser jedoch in ihnen auffallend beweglich ist." The removal of any water from the wood at the top of the tree caused a flow toward the point of loss, the demand for water being thus propagated in the walls to the roots, where it could be satisfied. It had been demonstrated that the forces at play in imbibition far more than sufficed for the elevation of the water; that the water moved easily in wood was certain. That it moved in the walls seemed to have been demonstrated by direct observation of air filling the lumina; by the experiment of Unger (1868), who injected the lumina with wax without preventing the movement of water; and later by Sachs' experiments with sharply bent tendrils, etc.

Sachs elaborated no new theory of imbibition to account for

the movement of water, Naegeli's micellar hypothesis being generally accepted, and accounting satisfactorily for the great force with which the water had to be, and is, held. As I understand the micellar hypothesis, it regards the water as held between the micellae by its surface tension; at any rate, it would say that imbibition and surface tension have a common mechanical explanation. This is not altered in the least by the fact that the presence of the spaces is dependent on that of the water. Since the spaces are indefinitely small, the tension is indefinitely great. In the evaporating surface these spaces become still smaller as they lose water, unless it is immediately replaced from behind, and the meniscuses formed in them are of such ultra-microscopical minuteness that it is easy to suppose they can draw water higher than any tree reaches. Assuming always that the walls were the path of the water, the imbibition theory was thus complete, and not in open discord with contemporary physical science. As this was not true of any other theory it was but natural that this one was generally accepted, and by a sort of reflex action this strengthened the faith in its premise as to the path.

The identity of imbibition and capillarity was postulated by DeLuc (1791:12), but on evidence—the imbibition of alcohol and ether—which has not been found generally sound. Hofmeister (1862:100) and Unger (1868), who were forerunners in the modern development of the theory, treated them as the same, as did Pfeffer in his unqualified acceptance of this theory in the first edition of his *Physiology*. Naegeli and Schwendener (Mikroskop. second ed. 380) say it is indifferent what the force is called, though formulae based on measurements of tubes of appreciable size need not apply in these invisible interstices. In 1865 (Handbuch, 213) Sachs entertained no doubt that capillarity and imbibition were related. In 1879 (Por. d. H.), however, he regarded the phenomena as distinct, and afterward became most insistent on the difference. This robbed the imbibition theory of its foundation in established physics, and it is very doubtful if it ever could have obtained general credence

in this form. The imbibitionists never offered any physical explanation of the supposed absence of high friction in the fine pores of the wood; this was dismissed as a "natural property" of the wood substance.

The imbibition theory fell with the disproof of its first premise, that the water moved in the walls. Unger's injection experiment was repeated with the opposite result. Elfving (1882:714) plugged the lumina of pieces of wood with cocoa butter and could force no water through them. Scheit (1884) injected sticks with gelatin with the same result. Vesque (1884:188) injected the tracheae of a living branch with cocoa butter and the branch wilted. Errera (1886, I, 31, II) repeated this experiment using gelatin; as did also Strasburger (1891:541). Dixon and Joly (1895) employed gelatin, paraffin, ice, and water vapor to obstruct the lumina, causing wilting in each case. Smith found the movement of water in cucumber stopped or very nearly so by injection with gelatin; the plugging of the spiral vessels by *Bacillus tracheiphilus* caused a gradual wilting, while *Fusarium niveum*, which fills the pitted vessels as well, causes a sudden collapse of watermelon foliage. Vesque (1884), Kohl (1885), and Darwin and Phillips (1885:366) made plants wilt, or checked the absorption as measured by the potometer, by squeezing them until the lumina were presumably closed. The old observation (DeVries) that if a transpiring branch is cut in the air it wilts was recognized as showing that plugging the lumina with air closed the path of the water (Scheit, 1886:172). Against the experiments with bent branches it was pointed out by Russow (1883:99) and Scheit (1884) that bending does not entirely close the lumina. And Dufour's inability to force water through the bends under pressure was ascribed by the opponents of his theory to the entrance of air where his wood was exposed in cutting.

The movement of water in the lumina was directly observed by a number of investigators, notably Vesque. The well-known presence in the lumina of colors and other substances used in detecting the path of the transpiration stream had been ascribed

to the abnormal direct atmospheric pressure against cut surfaces; but without reason, as Van Tieghem (1870:278 *seq.*) found decoctions absorbed by sound seedlings of Leguminosae confined to the lumina of the vessels. Once the imbibition theory was undermined, older objections to it, some of which Böhm had been constantly raising, were granted recognition. It was incontestable that lumina of at least a part of the conducting elements contained water; the imbibition theory could offer no explanation at all of its presence (Böhm, 1878:225; Sachs, 1887:247). The absence of a parallel between transpiration and absorption (McNab, 1874:356; Vesque, 1878) was therefore unintelligible to imbibitionists. The excessive difference in the facility of transverse and longitudinal movement of water was not intelligible on the basis of the distribution of the water of imbibition, the difference in other physical properties of the wood walls being relatively small. The drying out of dead branches of living trees would seem impossible according to the imbibition theory. And there are other minor objections to it which need not be touched upon here.

Our permanent debt to the founders and supporters of the imbibition theory is for placing great emphasis on the easy passage of water through the wood,[3] and for suggesting a physical means for this passage. The water cannot escape passing through occasional walls as it rises. And the work of Errera and of Dixon and Joly, already cited, testifies that some water, though far from enough to satisfy the demands of transpiration, can travel in the walls for a considerable distance.

VII. An active rôle in the elevation of the water has been ascribed by many writers to capillarity in the lumina of the elements of the wood.[4] At the same time it has been recognized

[3] Even this is disputed by Janse.

[4] Recognizing of course that capillarity is not an ultimate source of energy for the rise, but that this is furnished when the water is evaporated. It would indeed be a careless attempt at an explanation which should seek in capillarity the energy to keep a stream moving upward; still, I cannot agree with Kamerling that this would be a "logical error," since the law of the conservation of energy does not itself rest on logic.

that in tubes of such size as these lumina the lifting power of capillarity is not exceedingly great. In a glass tube 10μ in diameter this should be about 3^{m}. Strasburger (1891:87 *seq.*) found it less in tracheae than in glass, sometimes less than half as much. While the lifting power is determined by the form of the meniscus, it is possible enough that this should be influenced by the nature of the wall. In the absence of direct contrary evidence on the same subject, which is wanting in Schwendener's criticism (1892:912), Strasburger's statement must stand.

The efficacy of capillarity is limited again by the dilution of the air in the tracheae. Naegeli's classical work on capillarity (1866, I, II) showed experimentally that with diminishing atmospheric pressure the lifting power of a meniscus in a glass tube decreases; slowly at first, but rapidly when the pressure approaches zero. The theoretical ground for this is evident from the intimate connection between surface tension and vapor tension. Naegeli found the details to be remarkably dependent upon the temperature. Since the air in the tracheae is always rarefied when transpiration is at all active, and with excessive transpiration the loss of pressure is great enough sometimes to lead to the formation of bubbles of water vapor, the service which capillarity can perform in the elevation of water is most insignificant when the demand for water is most urgent. A repeated, but so far as I can see entirely unwarrantable assumption (Böhm, Ann. Sci. Nat. 1878:232; Elfving, 1885:536; R. Hartig, Bot. Zeit. 1883; Sanio) has been that each wall across the path of the transpiration stream furnished a fresh starting point for capillarity to work from. There is no reason why a wall should offer any greater resistance to movement of water downward in response to gravity than upward in response to capillarity.

The Jamin's chain has never been shown to have any advantage over a single meniscus in causing a movement of water. For every added meniscus with an upward pull there is one of the same shape whose concavity is downward. The resistance

offered by a long series of bubbles to longitudinal pressure has given the Jamin's chain a place in some theories (Westermaier, 1883; also Hartig, 1882; Vesque, 1884), as an arrangement to hold the water up, forces of a different nature being invoked to elevate it. Statements as to this resistance of the "chain" in glass tubes are very discrepant (Janse, Naegeli, Plateau — as cited by Strasburger, 1891 : 815 — Zimmerman, 1883); according to the experimental results of Schwendener (1886 : 569) and Strasburger (1891 : 819) the resistance to the movement of the chain as a whole is not usually very great in tracheae.

If the pressure against the upper end of such a column of air and of water were diminished or removed, the result would obviously be an elongation of the bubbles, lifting the water supported by them. This would operate most at the top, and would cease at a point down the column where the resistance to the bubble's expansion was equal to its excess of tension. In this way Schwendener (1893) thinks it likely that the diminished tension in the vessels might be able to lift some water as much as 15^{m} instead of the 10^{m} to which a pressure of one atmosphere could lift an unbroken column. Under certain imaginary conditions, which as Schwendener showed do not really occur in plants, a much greater height would be possible; Schwendener (1892 : 934) suggests such a case in which the bubbles should be 10^{mm} long, in which Steinbrinck (1894 : 127) showed that the top of the column might be lifted 142^{m}. As to the actual length of the bubbles, Schwendener puts the average in Fagus at 0.33^{mm}, that of the supported water being 0.14^{mm}. Both Schwendener and Steinbrinck seem to assume in their calculations that a meniscus will retain its full effectiveness in a vacuum, which, as has just been pointed out, is not at all the case. Moreover, such a mechanism, in lifting water, would accumulate air at the top, and so destroy itself, and therefore (Askenasy, 1895), even if it could lift water once, it could not raise a constant stream.

During the last decade surface tension has been playing a very prominent part in still another form in explanations of the ascent of sap. The cohesive power of pure water was demon-

strated by Naegeli and interpreted with an insight in advance of his time. He says (1866 : 498) "Viele Versuche zeigten, dass in frisch gezogenen Capillarröhren die Spannung negativ werden kann, ohne dass in dem ausgekochten Wasser Dampfbildung eintritt;" thus in one experiment the cohesion of the water sustained a mercury column 44^{mm} in excess of that in the barometer. Two other sentences outline Naegeli's interpretation: "Dieses Entzweireissen einer Wassersäule ist im Grunde nichts anderes als Dampfbildung in derselben[5];" and concerning the amount of resistance to such pulling apart, "Es wäre selbst möglich, das es dafür keine Grenze gäbe." Böhm cites Helmholtz on this same point, the passage referred to (1874 : 492) being on cohesion by very dilute sulphuric acid. Böhm himself in 1890 (Bot. Centralb. 268) found that Salix with boiled roots would absorb water and draw up mercury "Stets bis zur Barometerhöhe," when the total pressure of mercury in the water must have been above one atmosphere. Strasburger (1891 : 792) got the same result with branches of Taxus and Tsuga. Böhm then (1893 : 209) reported the lifting of mercury columns 22^{mm} above that of the barometer by Salix, and 161^{mm} above it by Thuja. In this paper Böhm seems to refer repeatedly to cohesion when he speaks of capillarity.

A little later than this, Askenasy (1895) published an exceedingly clear theory on the ascent of sap, in which the chief rôle in making the pull set up by evaporation in the leaves operative at indefinite distances down the trunk was ascribed to the cohesion of the water. The priority of the publication of most of this theory belongs to Dixon and Joly, who published abstracts of their work in 1894. The general acceptance of it is due more largely to Askenasy, whose name is usually associated with it. So is Strasburger's name, though he has not publicly subscribed to it, and it is not in harmony with all of his work. Like the imbibition theory, this one was complete in that the premises, proven and assumed, were an adequate foundation for the conclusion; the factors, as the theory used

[5] Physicists are not agreed on this.

them, were equal to their work. Its acceptance was naturally prompt and widespread, giving a new interest to the study of the cohesion of water from the physical side. Askenasy (1896: 441) was able to draw up mercury 82^{cm} and again 89.3^{cm} by a pull resulting from evaporation from a plaster of Paris surface. Dixon and Joly (Trans. Roy. Soc. 1895: 570), by a method better calculated to indicate very great tensions, demonstrated that columns of water could endure a longitudinal pull of more than seven atmospheres before breaking, and that this was possible without absolute freedom from gas, and with bits of Taxus wood in the water. By the same method Berthelot had obtained negative tensions, since variously estimated at 50 to 150 atmospheres There is a résumé of some other work, including some of Lehmann's own, in his *Molecularphysik* (I: 243–5), in which Naegeli is overlooked. Kamerling (1898: 465) showed on theoretical grounds, the same as Naegeli's must have been, that in pure water *at rest* the resistance to pull must be infinite.

The supposed difficulty with other theories which the cohesion theory sought to overcome was their failure to provide for the transmission of really negative tensions, *i. e.*, tensions more than one atmosphere less than the normal. So long as the tension remains positive there is no possibility of the exercise of cohesion; the least positive tension would itself prevent a rupture of a column, whether of water or of water and air. But it is argued that water can be lifted 10^{m} at most while its tension remains positive; that when it is lifted higher, as in trees everywhere, negative tensions *must* be present near the top. There are two easy ways of determining empirically the opportunity for the play of cohesion in the plant: measuring the tensions actually present, and testing the result of artificially established tensions.

We have already mentioned that the tension of the air is ordinarily less than one atmosphere, and of course that of the contiguous water is the same. Well known to older writers, but too little considered, this fact came strongly to the fore with v.

Höhnel's work (1879). He found (p. 113) that a suction of 40–50^{cm} Hg was not rare as late in the year as the end of October. Böhm (1877) found a suction by Crataegus of 61^{cm}; by Syringa and some Pomaceae of 25^{cm}; and by Platanus of only 16^{cm}; and (Bot. Zeit. 1881: 824) even in March a suction by Crataegus of 40^{cm}. In one experiment (Bot. Zeit. 1881: 819) mercury was jerked into a vessel of Robinia 117^{cm}, but this was not a rise of that distance.

In 1890 Böhm said that Salix with boiled roots would exert a suction sufficient to lift mercury, as already quoted, "Stets bis zur Barometerhöhe." In 1893 he said that it was in "successful" experiments that the mercury could be drawn as high as the barometer by shoots whose lower end had been cooked; but only three experiments in 400 succeeded. In one of these three the indicated suction was 2.2^{cm} over an atmosphere. We have already noted his results with conifers. Strasburger (1891: 787) reports as the greatest observed suction in any herb 28^{cm} Hg (*Amaranthus caudatus*); in live branches of dicotyledonous trees, 54^{cm}; in branches whose lower end was boiled, 67^{cm}; and in conifers similarly treated, 70^{cm}. Vines (1896) reported suctions of 116^{mm} and of 11 inches by *Helianthus annuus*, 320^{mm} by *Prunus Laurocerasus*, 21¼ inches by *Fagus sylvatica*, and 22¼ inches by Taxus. These pressures are to be subtracted not from zero, but from one atmosphere (Vines, Annals of Botany **10**: 644). Data obtained by Th. Hartig, Schwendener (1886), and others, by inserting manometers in the trunks of transpiring trees, agree that tensions of zero are not closely approached. A part of these figures may be lower than they should be, because they only indicate the point at which air came out of the cut end of the stem and prevented the absorption of any more water.

On the other hand, figures obtained after removing air by boiling or sucking it out of the cut end are likely to be too high. There is no doubt that the transpiring cells could draw water from the tracheae in spite of an absolute pull; that tensions of zero or less are not transmitted and used to absorb water is

because the air in the tracheae expands until finally it closes them to the passage of water. Removing a part of the air makes a lower tension necessary for what is left to plug the tracheae and so permits more than the normally possible suction. I have illustrated this with a small branch of a greenhouse grown Eucalyptus, the cortex removed, inverted so that when any bubbles were drawn from the stem they could not stay in contact with it and prevent the absorption of more water. It was in air-tight connection with a tube 1^{mm} in diameter, full of water and standing in mercury. The mercury rose in one hour and fifteen minutes 101^{mm}, where it was stationary. This suction was increased to 191^{mm}, but drew air from the pith and wood, and fell slowly to 106^{mm}. A little air continued to be extracted, but the suction increased, until 52 hours after the experiment began it was 173^{mm}; and after 79 hours 235^{mm}. The rise of mercury had become very slow, and at this point a leak stopped the experiment. The young leaves, up to those more than half grown, were already becoming dry, though the cut end was, and had constantly been, in water. It is because the possible suction is chiefly a function of the air in the tracheae that Vines (1896: 538) finds that a large part of the leaves may be removed from a branch without much effect on the suction. For the same reason—because a part of the tracheae are closed—a suction of less than the greatest the transpiration stream can exert may nearly stop the absorption of water (Vesque, 1884; Strasburger, 1891: 788). It seems clear to me that the evidence we have warrants the conclusion that the tensions in the tracheae of living plants—at least of dicotyledons—in nature are never even approximately as low as zero.[6]

What happens if the tension is artificially lowered? Böhm (1864: 546) put more than a hundred Salix cuttings in a vessel where the pressure against the absorbing ends was reduced to 8 to 10^{mm} Hg. The result was "Dass die Blätter nach zwei oder höchstens drei Tagen vertrocknet waren. Das Absterben

[6] This was treated as an established fact by Naegeli and Schwendener (1877: 380).

erfolgte in der Regel bei kleinen Reichbeblätterten Pflanzen schneller als bei grösseren wenig beblätterten," etc. Böhm's conclusion (562), "Dass die zum Saftsteigen erforderliche Kraft von dem Luftdrucke geliefert werde," is equivalent to saying that an actually negative tension cannot be exerted to absorb the water. Vesque (1884), working with sound water cultures of oleander, found that the absorption became impossible when the tension was one atmosphere *minus* 63^{cm} Hg. Strasburger (1891:793), Scheit (1886, II), and Janse (1887:3–10) all agree that dicotyledons wilt if water is available under too low a pressure, and that the removal of nearly the whole atmospheric pressure always makes it too low. Saussure (p. 30 of Ostwald's *Klassiker* no. 16, p. 214 of original) describes a somewhat different experiment explicable in the same way; vessels containing plants with their roots in water were placed *in vacuo* and lived for weeks, and even grew, if protected from direct illumination. Under the conditions the plant was in an atmosphere saturated with water and did not transpire. Water may have diffused rapidly enough to supply the demands of what growth occurred in a "vacuum." In direct light the plants dried up, because the leaves became warmer than the air, and water evaporated from them and could not be replaced.

We have found not only that negative tensions do not occur in dicotyledons in nature, but that an artificial elimination of the positive tensions to which they are accustomed robs them of the power to absorb and elevate the transpiration stream. There have been some premises and *a priori* arguments for the cohesion theory which, for the sake of thoroughness, we will still consider. Berthelot says (p. 332–3) "À ce moment (when negative tension has been caused by cooling) le moindre choc ou broissement, la moindre vibration fait reparaître à l'instant, avec une sorte d'ébullition, un léger bruit et une secousse plus ou moins notable, le gaz dissous dans l'eau." Lehmann (p. 244), speaking of water under a tension of one atmosphere *minus* 1,200 ^{mm} Hg, says "Erst bei erschütterungen volgt in solchen Fällen das Sinken zum normalen Standpunkt." Donny seems to be

alone (according to Lehmann) in reporting that a jar did not instantly release any negative tension, and his tension was only that of one meter of water. Trees are almost never absolutely at rest; their very agitation by the wind has served once (Spencer) to explain the rise of water. Kamerling, in the same mathematical argument showing that the cohesion of pure water at rest is not limited, proves that the kinetic energy of moving water may easily pull it apart. The transpiration stream not only moves, but moves irregularly, which no negative tension could survive. Because trees are not at rest and the transpiration stream is in unsteady motion, we must regard any negative tension in it as *a priori* impossible.

While Dixon and Joly (1895:571) regard a continuous column of water as an essential assumption in their theory, and base it on Strasburger's statement that there is very little air in the youngest wood, Askenasy, adhering more closely to Strasburger, recognizes that the presence of some air is not an effective bar to the movement of water in the same tracheae, and seems to expect cohesion to operate around and past bubbles. I cannot see the possibility. We believe cohesion to depend on the fact that the first break in a column of water must be an infinitely small bubble, whose surface is a meniscus of infinitesimal radius and a correspondingly great surface tension. In the wood bubbles are present of a very appreciable size. When transpiration is most active, and cohesion is supposed to be most necessary, these bubbles stretch and become practically cylinders. Midway up its side the surface of such a bubble is very much nearer that of a cylinder than of a sphere. The surface tension of such a meniscus hardly deserves the name of capillarity; cohesion is out of the question. The low tension of the bubble still further depresses the surface tension.[7]

Capillarity and cohesion are usually names of manifestations of surface tension under different conditions. Applied to its

[7] In a glass tube open at one end, the shape of the meniscus itself is a function of the tension of the gas; in the case we are considering this is not quite true, because the shape of the tracheae helps to determine that of the bubble.

manifestation in the single fixed set of conditions we have in the tracheae, they are not distinguishable. Ten years ago Böhm alone imagined (publicly) that capillarity could play the leading rôle in the ascent of sap. It had been tried and found wanting. Then it was named cohesion and sprang at once into popular favor.

I have been assuming that the transpiration stream does not rise in tracheae entirely free of bubbles. The evidence for this is unlimited. It was formerly taken as an established fact, and the imbibition theory rested very largely upon it. Since this theory collapsed, Schwendener has shown again by most careful work that when transpiration is active continuous water "threads" are wanting. The experiments of Strasburger (1891 : 681–6), on which Dixon and Joly rest their case, were obtained in this way: branches were cut, under water if possible, and left standing in shade or darkness for some hours, until they had all the water they would hold; then they were examined and the youngest wood, which is most active in conducting water, was found to "contain very little air," or "the air could be detected with difficulty." It is easy to substantiate this observation. The subject of experiment has absorbed all the water it can, with the help of the whole pressure of the atmosphere, so there is no opportunity for the demonstration of cohesion, however abundant and continuous the water. The experiment gives no clue to the water content and its distribution when transpiration is active and water less accessible, and cohesion might be of service. Hartig (1888) and Wieler (1888), among others, have shown conclusively that it is just in this youngest wood that the water content is exceedingly variable, dependent on the supply and demand. Von Höhnel (1879 : 126) found the lowest tension in the youngest ring. And an experiment of Böhm's, already cited, shows that in the case of Robinia, one of Strasburger's few dicotyledonous subjects, active transpiration leaves the vessel far from full of water. The following experiment hits the question squarely; it also covers the other question of movement past bubbles, on which a superfluous amount of evidence is not yet in print.

A young branch of *Eucalyptus globulus*, with ten pairs of expanded leaves, all horizontal, stood in water four hours. The xylem was then full of water, excepting the large pitted vessels which contained bubbles occupying about half of their volume. Both sides of the stem for 2^{cm} were cut away almost half through, leaving only a very thin strip, which was protected against desiccation with vaseline. The structure was so fine that in the outer part of the xylem only the pitted vessels were clear cut and individually distinct. The lower end of the branch was tied into a glass tube containing a little water over a meter of Hg, the other end of which tube was swung down so as to subject the cut end to a pressure of 9^{cm} Hg instead of 74^{cm} (the atmosphere). Within five minutes the water began to disappear from the pitted vessels, which were soon visibly empty. The spiral vessels (primary) were but little later losing their water; while it was more than half an hour before the lumina of the wood fibers became generally empty. During the first part of this time the cut end was in contact with water, the rubber tube connecting the plant with the glass tube being bent 180°, so that air escaping from the branch would not collect against it. The branch used up its stored water, then, not because other water was not at hand, but because it cannot absorb it when the pressure is only 9^{cm} Hg. After about fifteen minutes the subject was kept horizontal under the microscope and very likely water was no longer kept against the cut end. To this point the experiment showed that, as Strasburger found, while the conducting part of the wood fills with water when it may be absorbed under the full atmospheric pressure, its lumina become empty again when this pressure is removed. When the leaves are called upon to exert a great suction, the continuous threads of water whose cohesion might transmit it do not exist.

After the lumina became free of visible water, the suction was removed, and the branch set in water for three minutes. Then eosin was given drop by drop to the cut end. It was eagerly absorbed, showing that the lumina had not filled to any considerable extent with air from outside. Watching for the eosin with the naked eye, it was between four and five minutes before

I detected it in the thin strip; then it had traveled the whole length of it on one side of the pith, nearly the whole on the other. It was absolutely confined to the spiral (primary) vessels, next the pith, and was about equally distributed in three to five layers of these. Twenty minutes later, isolated vessels outside of these (not the pitted ones) were injected. It was exceedingly evident in these isolated vessels, as I had been able to make out quite unsatisfactorily in the inner spiral ones where the whole group was red, that columns of colored water were separated by bubbles. With a high magnification I was able in a few places, where the thickness of the wood did not interfere too much, to see a very distinct red film lining the wall and connecting the indices of red liquid. It must be remembered that these vessels were the first in their immediate neighborhood to carry the eosin. It seems to me that the conclusion is warranted that the bubbles are not an appreciable obstacle to the passage of the water. Strasburger describes exactly the same case.

To summarize the discussion of the cohesion theory: It is applicable only in explaining the transmission of negative tensions; but negative tensions do not occur, nor do the positive tensions present approach zero; the movement of water is prevented by artificially removing the normal positive tensions; if negative tensions could arise they would be immediately released as a result of the movement of the water and the agitation of the trees; more than an insignificant negative tension is impossible in the presence of free gas or a vacuum, as the only bar to the enlargement of the bubble is its surface tension, and this decreases with the pressure; when the tension is low and transpiration is active, there are bubbles in all water conducting elements.

[*To be concluded*].

A REVISION OF THE GENUS NEMOPHILA.[1]

HARLEY P. CHANDLER.

(WITH PLATES II–V)

THE North American genus Nemophila is represented by fourteen species and four varieties. Two species belong to the southern states, one primarily to the Rocky mountains, and the remainder to the Pacific slope, principally California.

It is one of the genera in which the tendency to variation is very strong, and this has been the source of much error and confusion in classification. Many of the common species were described by Europeans who were innocent of field experience on the Pacific coast, and this quite naturally resulted in mistakes. The types of these species have not been easily accessible to American botanists and confusion has been worse confounded by their diverse interpretations of the meager published descriptions.

The present paper was undertaken in the hope first of clarifying the synonomy. To this end original descriptions have been freely consulted, some forty type specimens have been examined, and drawings of two types have been obtained from Europe. Exhaustive lists of acknowledged synonyms have not been introduced, but all disputed names and those of recent publication have received attention. The second and more important hope of the writer was to contribute something to our knowledge of the plants themselves, by a study of their variations in the field, as well as in the herbarium. The best way of expressing both classes of results seemed to lie in a revision of the genus.

Discussions of the various characters available for discriminating forms will be found in the remarks following the descriptions of certain species. Here it will suffice to say that the

[1] Contributions from the Botanical Laboratories of the University of California.

almost infinite variation makes an accurate limitation of species absolutely impossible; and most of the species as here described include a great variety of more or less inconstant forms. Were these all described they would fill a volume, but nothing would be gained thereby. Convenience should be the aim of classification, and this aim is most effectually defeated by the multiplication of uncertain species.

To avoid possible uncertainty in interpreting the descriptions, it should be said that measurements of leaves are given as including the petiole; but the outlines as including only the blade, except where there is a conspicuously tapering base.

The question of the relation of Nemophila to Ellisia is vital, but must be left for future consideration.

The writer is indebted to the following persons for assistance in the preparation of this paper, principally by the loan of specimens: Mr. and Mrs. T. S. Brandegee, Miss Alice Eastwood (for the California Academy of Sciences), Dr. J. N. Rose (for the United States National Museum), Mr. S. B. Parish, Mr. H. M. Hall, Mr. J. P. Tracy, Prof. W. R. Dudley, Mr. Leroy Abrams, Mr. J. G. Lemmon, Prof. Aven Nelson, Prof. C. V. Piper, Mr. W. C. Cusick, Mr. Thomas Howell, Mr. Geo. Hansen, Mr. M. L. Fernald, Prof. L. F. Henderson, Prof. A. J. Cook, Mrs. Mary H. Manning, Miss Winifred Paine, Mr. R. H. Platt, Mr. W. N. Suksdorf, and Mr. Ralph Hopping. Special acknowledgment is due to the members of the Department of Botany of the University of California, and particularly to Prof. W. L. Jepson, at whose suggestion the study was first undertaken and whose constant encouragement and advice have been invaluable.

KEY TO THE SPECIES.

Flowers 1 cm or more across (except no. 2).
  Leaves (at least the upper) alternate; seeds less than 5.
    Angles of stems and often veins of leaves beneath retrorsely prickly.
      Petioles broadly winged and auriculate-clasping; flowers 1 to 3 cm across - - - - - - - - - - - - 1. *N. aurita*
      Petioles not winged nor auriculate-clasping; flowers less than 1 cm across - - - - - - - - - - 2. *N. racemosa*

Angles of stems not prickly.

Branches 2 to 6 dm long; all but the earliest leaves alternate; corolla 1 to 3 cm across, blue - - - - - - 3. *N. phacelioides*

Branches 0.5 to 2 dm long; only the upper leaves alternate; corolla 1 to 2 cm across, violet with whitish green-spotted center - 4. *N. Kirtleyi*

Leaves mostly opposite; seeds usually 5 or more.

Corolla white with a dark purple spot at the tip of each lobe; scales oblong, half free, rolled toward the filaments - 5. *N. maculata*

Corolla blue or white without a spot at the tip of each lobe.

Corolla deep or pale blue, often veined with deeper blue and dotted toward the center; scales mostly broad, wholly adherent or free at the tip; cotyledons spatulate - - - - 7. *N. Menziesii*

Corolla white or pale blue.

Cotyledons spatulate; corolla-scales linear, wholly adherent. 8. *N. Menziesii atomaria*

Cotyledons with orbicular or oval blade; corolla-scales oblong or linear, part free - - - - 9. *N. Menziesii integrifolia*

Flowers 1 cm or less across.

Corolla tubular or tubular-campanulate.

Corolla equaling or longer than the calyx.

Leaves opposite; seeds more than 1; Pacific coast.

Leaves oblong (rarely ovate) in outline, pinnately 5 to 7-lobed; corolla-scales linear, often reduced to hairy lines; seeds 2 to 12 (mostly 6 or 8) - - - - - - 11. *N. pedunculata*

Leaves spatulate in outline, 3 to 5-toothed or -lobed at the tip, with cuneate base; corolla-scales small and laciniate, or obsolete. 12. *N. spatulata*

Leaves mostly ovate in outline, pinnately about 5-lobed, the upper 3 lobes confluent; corolla-scales minute, various.

Plant hispid; lobes of leaves usually sharp; peduncles mostly shorter than the leaves; Washington to the Coast ranges of California - - - - - - - 13. *N. parviflora*

Plant with softer, spreading pubescence; lobes of leaves more rounded, the lower sinuses shallower; peduncles mostly exceeding the leaves; foothills of the southern Sierra Nevada. 14. *N. parviflora quercifolia*

Leaves alternate, mostly triangular-ovate, 3 to 5-lobed; seeds mostly 1 or 2; southern U. S. - - - - - - 15. *N. microcalyx*

Corolla mostly shorter than the calyx; leaves mostly alternate; seeds 1. 16. *N. breviflora*

Corolla open-campanulate or pelviform.

Leaves opposite, oblong in outline, with 5 to 7 oblong lobes pinnately arranged; corolla mostly open-campanulate, not hairy within; scales linear, often reduced to hairy lines - - - 10. *N. sepulta*

Leaves opposite, spatulate, elliptical or lanceolate in outline, shallowly 3 to 5-lobed at the tip or entire; corolla mostly open-campanulate, often hairy at the center; scales oblong to linear, often half free, or reduced to hairy lines - - - - - - - - 6. *N. humilis*

Leaves, especially the upper, sometimes alternate, typically with 5 to 9 suborbicular petiolulate pinnately arranged lobes, but very diverse; corolla mostly pelviform, not hairy within.

Calyx-appendages evident; corolla white or bluish; scales various. 17. *N. exilis*

Calyx-appendages minute or obsolete; corolla usually deep blue; scales linear, ciliate - - - - 18. *N. exilis pulchella*

1. N. AURITA Lindl., Bot. Reg. *t. 1601.* 1833.—Plant weak and straggling, leaning on other plants for support: branches 2 to 6 dm long, hirsute, angled or winged, the angles armed with sharp prickles which aid in climbing: cotyledons not seen: leaves all but the lower alternate, 5 to 15 cm long, more or less deeply pinnatifid into mostly 7 to 13 entire or shallowly lobed downward-pointing divisions; retrorsely barbed along the principal veins beneath; petioles winged, expanded below into an auriculate-clasping base: flowers mostly in very loose naked racemes at the tips of the branches: calyx-lobes lanceolate, 4 to 10 mm long; appendages usually less than a third as long, spreading: corolla with a short throat constricted below the top and spreading limb 1 to 3 cm across, violet, paler outside; scales triangular, usually fimbriate, below covering the base of the stamens, above turning away from them, often 3 mm long: nectaries prominent, one between each pair of scales: style 2 or 3 times as long as the ovary, cleft only at the tip: capsule globular, 5 to 9 mm in diameter, thin-walled: seeds 4 per capsule, globular, 1.25 to 3 mm in diameter, conspicuously favose-reticulated; caruncle none (?).

The whole plant is prickly, sometimes even to the calyx.

CALIFORNIA AND ARIZONA.

Specimens examined: CALIFORNIA: Plumas co., *Mrs. Austin;* Stockton, *Sanford* no. 188; Kaweah river basin, *Hopping* no. 41, *Woolsey;* Bear creek, Tulare co., *Purpus* no. 1298; Kernville, *Brandegee;* Niles, *Hall* no. 1648; Palo Alto, *Dudley;* Bixby creek, Monterey co., *Brandegee;* Monterey co., *McLean, Plaskett;* San Luis Obispo, *Lemmon;* Dos Pueblos,

Santa Barbara co., *Brewer* no. 396; Casitas pass, Ventura co., *Hall* no. 3136; Santa Cruz island, *Brandegee;* Fort Mojave, *Lemmon;* Los Angeles, *Hasse;* Santa Monica cañon, *Barber* no. 53; Fallbrook, San Diego co., *Hall* no. 515; Del Mar, San Diego co., *Brandegee.*

ARIZONA: Diamond creek cañon, *Norman C. Wilson.*

The type was probably raised from seed sent by Douglas, who collected principally at San Francisco and Monterey, and is most likely in the herbarium at Kew or at the British Museum.

2. N. RACEMOSA Nutt., in Gray Proc. Am. Acad. **10:** 315. 1875.—Near *N. aurita*, but less prickly: cotyledons with orbicular blade and long petiole: the leaves shorter and broader in outline and with fewer divisions, these more often toothed or lobed; petioles never broadly winged nor auriculate-clasping: flowers less than 1 ^{cm} across, more plainly racemose: corolla-scales narrow, often half free, sometimes obsolete.

SOUTHERN AND LOWER CALIFORNIA.

Specimens examined: CALIFORNIA: Santa Cruz island, *Brandegee;* San Clemente island, *Nevin & Lyon;* Cajon heights, San Diego co., *Eastwood;* Del Mar, San Diego co., *Brandegee;* San Diego, *Alderson* no. 1007, *Brandegee, Setchell.*

LOWER CALIFORNIA: Guadalupe island, *Anthony* no. 254, *Brandegee, Francheschi* no. 32, *Greene;* Cedros island, *Brandegee;* San Martin island, *Anthony* no. 229, *Brandegee;* Estaban, *Brandegee.*

Type locality, "California; San Diego, Nuttall. Island of Catalina, Dall & Baker."

3. N. PHACELIOIDES Nutt., Jour. Acad. Philad. **2:** 179. 1822.—Plant weak: branches 2 to 6 ^{dm} long, spreading- or retrorse-hirsute: cotyledons not seen: all but the earliest leaves alternate, pinnately divided into 3 to 9 oblong, oval, or obovate, 2 to 5-cleft divisions, the upper three divisions confluent, the others often distant: lower flowers terminal (though apparently axillary), the upper loosely racemose: calyx-lobes lanceolate or oblong, 5 to 10 ^{mm} long; appendages ovate or oblong, about half as long, not reflexed: corolla pelviform, 1 to 3 ^{cm} across, blue; scales broad, sometimes part free, fimbriate: style twice as long as the ovary, cleft for a third its length: capsule about 5 to 9 ^{mm} in diameter: seeds 4 per capsule, "obscurely compressed-punctate," according to Gray.

Only very scanty material of this species was accessible.

ARKANSAS AND TEXAS.

Specimen examined: TEXAS: Waco, *Miss S. A. Trimble.*

Type locality, Arkansas.

4. N. KIRTLEYI Henderson, Bull. Torr. Bot. Club **27**: 350. 1900.—Plant weak, diffuse: stems 5 to 20 cm long, often purplish, hispid with spreading or retrorse hairs: cotyledons spatulate: upper leaves alternate, lower ones opposite, all triangular-ovate in outline, pinnately parted into usually five oblong or ovate, entire or 1 or 2-toothed divisions: peduncles exceeding the leaves: calyx-lobes lanceolate, 4 to 8 mm long, enlarging in fruit, minutely pubescent and long-ciliate; appendages lanceolate to ovate, a third as long or less: corolla pelviform, little exceeding the calyx, 1 to 2 cm across, "with violet border and whitish center, conspicuously green-spotted near the junction with the stamens;" scales broad, trapeziform, strongly fimbriate on the free edge: style nearly twice as long as the ovary, cleft for a third of its length: capsule globular or slightly elongated, 4 to 7 mm in diameter: seeds 2 to 4 per capsule, ovoid, 2 to 3 mm long, deeply pitted, the pits covered with deciduous scales; caruncle cap-like, evanescent.

IDAHO AND EASTERN OREGON. May be looked for in northeastern California.

Specimens examined: IDAHO: Florence, *Henderson* no. 3082 (co-type). OREGON: Pine creek, *Cusick.*

The type locality is Salmon river hill, beyond Florence, Idaho county, Idaho, and the type specimen is in the National Herbarium.

5. N. MACULATA Benth., Jour. Hort. Soc. Lond. **3**: 319. 1848.—Branches ascending or decumbent, 10 to 30 cm or more long, from almost glabrous to strongly hispid: cotyledons spatulate: leaves opposite, the lower 3 to 5 cm or more long, pinnately parted into 5 to 9 ovate or sub-orbicular, mostly 1 to 3-lobed divisions; the upper shorter, usually with but 3 or 5 entire lobes at the tip and a cuneately tapering base, or lanceolate and entire: peduncles surpassing the leaves: calyx-lobes oblong-lanceolate to ovate, 4 to 10 mm long; appendages lanceolate to linear, one fourth to one half as long, reflexed: corolla pelviform, 1 to 4 cm across,

much exceeding the calyx, white with a dark purple spot at the tip of each lobe and rows of purple dots radiating from the center; scales oblong to oblong-linear, half free, mostly rolled toward the filaments, ciliate, 2 to 3 mm long: style cleft about a third its length, 2 or 3 times as long as the ovary: capsule globular, 3 to 10 mm in diameter: seeds usually 5 to 12 per capsule, globular or slightly elongated, 1.5 to 3 mm long, sparingly pitted, scaly.

This Nemophila shows three types of leaf and they are not infrequently all found on one plant. The lowest leaves are deeply pinnate, resembling those of *N. Menziesii;* the next are shallowly lobed at the very tip, and have a long cuneate base; while those at the ends of the branches are often lanceolate and entire. The second form is the most common and characteristic. Depauperate specimens are not rare. The original collector called the plant *Nemophila speciosa*, but this name was not published with a description.

SIERRA NEVADA MOUNTAINS, MOSTLY BETWEEN 2,000 AND 5,000 FEET ALTITUDE.

Specimens examined: CALIFORNIA: Forbestown, Butte co., *E. Brooks;* Penn valley, Nevada co., *Jepson;* Placer co., *Bolander* nos. 4551 and 4566; Rose springs, El Dorado co., *M. H. Gates;* Clinton, Amador co., *Hansen* no. 88; Calaveras Big Trees, *Brewer* no. 2098, *Brandegee*, *Greene;* Pine ridge, Fresno co., *Hall & Chandler* no. 167; Kaweah river basin, *R. Hopping* no. 138; Mineral King and Coburn mills, Tulare co., *Brandegee;* Tulare co., *Purpus* nos. 1732, 3059, and 5706.

The type was raised in England from seed collected by Mr. Hartweg on an excursion "along the right bank of the Chuba [Yuba] river to the mountains [Sierra Nevada]." It is probably in the herbarium at the Royal Gardens, Kew.

6. N. HUMILIS Eastwood, Bull. Torr. Bot. Club **28:** 150. 1901.—*N. Congdoni* Eastwood, *l. c.* 151.—In vegetative characters resembling *N. maculata:* leaves spatulate, elliptical, or lanceolate in outline, like the middle and upper leaves of that species: peduncles about as long as the leaves: calyx-lobes only 2 to 5 mm long; the appendages a third as long: corolla open-campanulate, 5 to 10 mm across, without a purple spot at tip of each lobe, but often with purple dots toward the center; scales from broad, laciniate and often half free to mere hairy lines which are often obscured by a mass of loose hairs at the center of the corolla: style once to twice as long as the ovary.

The available material of this species is unsatisfactory and it needs study in the field. Its affinity seems to be closest with *N. maculata*, from which it is readily distinguished by its smaller flowers, destitute of the purple spot at the tip of each corolla-lobe. It inhabits higher altitudes than that species.

SIERRA NEVADA MOUNTAINS FROM MARIPOSA COUNTY NORTHWARD.

Specimens examined: CALIFORNIA: Emigrant gap, Placer co., *M. E. Jones;* Summit, Placer co., *Eastwood* (type); Deer Park inn, Placer co., *C. J. Fox, Jr.;* Tioga road and Hetchy Hetchy road, Tuolumne co., *Congdon;* Hogan mt. and Konitz's place, Mariposa co., *Congdon.*

Type in the herbarium of the California Academy of Sciences, San Francisco, collected "on the trail between Summit and Summit Soda springs, in Placer county, June 9, 1898," by Miss Alice Eastwood, who states that it grew on a bank where the ground was still wet from the recently melted snow.

N. MENZIESII H. & A., Bot. Beech. Voy. 152. 1833, not of Syn. Fl., Bot. Cal., etc.—*N. insignis* Benth., Trans. Hort. Soc. n. s. **1**: 479. 1835. *N. liniflora* F. & M., Sert. Petrop. fol. & t. 8. 1846. *N. heterophylla* F. & M., *l. c.* *N. modesta* Kellogg, Proc. Cal. Acad. **7**: 93. 1877. *N. intermedia* Bioletti, Erythea **3**: 141. 1895. *N. Brandegei* Eastwood, Bull. Torr. Bot. Club **29**: 471. 1902. *N. macrocarpa*, Eastwood, *l. c.*—Branches slender or stout and succulent, ascending, mostly 10 to 25^{cm} long, more or less hirsute-pubescent with spreading or appressed, not always retrorse hairs: cotyledons usually spatulate: leaves mostly opposite, the lower 4 to 9^{cm} long, pinnately divided into 5 to 9 oblong, ovate, or suborbicular, mostly 2 or 3-lobed or -toothed divisions; upper leaves reduced and less divided in proportion to their distance from the root: peduncles slender, spreading, usually twice as long as the leaves: calyx-lobes lanceolate or ovate-lanceolate, 4 to 10^{mm} long; appendages lanceolate to linear, half as long or less: corolla pelviform, divided about three-fourths the way to the base, 1 to 3.5^{cm} across, from light to deep blue, veined deeper blue or purple, lighter-colored and often dotted, but seldom hairy toward the center; scales varying from broad and wholly adherent to narrow and part free, laciniate, ciliate or entire, often crisped: style 2 to 4 times as long as the ovary, parted for about a third its length: capsule elongated-globular, 5 to 10^{mm} in diameter: seeds 5 to 25 per capsule, 1 to 2^{mm} long, oblong-

ovoid or globose, scaly, rough, with a few deep pits; caruncle stipe- or cap-like.

Commonly called "baby blue eyes." Like all other Nemophilas, this species is exceedingly variable and sufficient allowance has not been made for the fact by some authors. It is particularly susceptible to moisture conditions. Where the soil is wet we find a succulent plant with sparse pubescence; where it is merely damp these characters are less pronounced; and where it is very dry the other extreme is reached — a very slender plant with dense pubescence. The variations in color are also striking (see note to the variety *atomaria*). Near the foggy coast of northern and central California the flowers are pale blue, usually dotted toward the center; in the Sacramento and San Joaquin valleys and in the sunny south coast ranges a deeper color predominates; while in southern California, which is practically desert except where reclaimed by man, a still more intense color is found. This is in accord with the common observation that in deserts flowers are brighter than in moister, less sunny regions; and since there are no accompanying variations which are at all striking, there seems to be sufficient reason for regarding as one species what a lay observer might distinguish as several different forms.

While mostly hermaphrodite, flowers with sterile anthers are occasionally found. They are smaller and deeper-colored than the others and according to Miss Alice Eastwood[2] they are associated with a more robust habit in the plant. Her investigations indicate that there is no marked difference in the seed-producing qualities of the two sorts of flowers.

There has been much confusion in the application of the specific names *Menziesii* and *insignis*, and the writer has investigated the matter with some care. The *Botany of Beechey's Voyage* was issued in parts. Page 152, on which the description of *N. Menziesii* appeared, is in Part 4, issued in 1833,[3] two years before the publication of *N. insignis*. On page 372 (Part 8, 1840) an expanded description is given and two forms, α and β, are noted: "α. corolla calycem vix duplo superante" is stated to be the form described on page 152; "β. corolla calycem plus duplo superante" is given as equivalent to *N. insignis*, which had been published in the time between the issuance of pages 152 and 372. Hooker and Arnott, then, who were co-workers with Bentham and probably had seen the type *N. insignis*, found nothing to distinguish that species from *N. Menziesii* except a slight difference in the relative size of corolla and calyx, a character in which the field student of these plants cannot but recognize considerable variation. Indeed, Hooker once declared that *N. insignis* ought to be called *N. Menziesii*.[4]

[2] Erythea 3 : 152.

[3] See Jackson, in Journal of Botany 31 : 298.

[4] Bot. Mag. *t.* 3774.

As for the original descriptions, each easily includes the other. The only possible remaining ground for separating the two species lies in the fact that Hooker and Arnott describe their plant as having leaves precisely like those of *N. parviflora*. There is no large-flowered species which has leaves of that style except *N. phacelioides*, with which they were well acquainted and which does not grow in the same part of the continent as *N. Menziesii*. Moreover, had the leaves been essentially different from those of *N. insignis*, Hooker and Arnott would surely have made note of the fact in contrasting forms α and β.

These considerations seem to the author to establish the identity of *N. insignis* with *N. Menziessi*, and the priority of the latter name.

Dr. Fischer de Waldheim kindly sent to the Herbarium of the University of California a flowering branch from the type specimen of *N. heterophylla*. An examination of this and a consideration of the original description (which, by the way, it contradicts in having the upper leaves always opposite and never sessile) show that it is one of the countless forms of *N. Menziesii* (not of *N. parviflora*, as Gray and others have thought). *N. liniflora* is another of these forms. Had Fischer and Meyer themselves collected in California, they would have known better how to allow for variation in Nemophila.

In the expanded description of *N. Menziesii* referred to above, we find "corollae (caeruleae parce nigro-punctatae) . . . ." If the corolla is dotted, it is probable that the type is the form most common in the north coast ranges of California, namely, that which Mr. Bioletti has separated as *N. intermedia*. But such a consideration aside, *N. intermedia* is not a good species (see above and note to *N. Menziesii* var. *atomaria*).

THROUGHOUT CALIFORNIA, EXCEPT IN THE NORTH AND THE HIGH MOUNTAINS.

Specimens examined: CALIFORNIA: Ukiah, *Purdy;* Mendocino co., *Chandler;* Ft. Ross, *Davy* no. 1673; Adobe cañon, Sonoma co., *Michener & Bioletti;* Santa Rosa cañon and Kenwood, Sonoma co., *M. S. Baker;* Vacaville, *Jepson, Platt;* Mt. Tamalpais, *Chandler* no. 281; Angel island, San Francisco bay, *Michener & Bioletti;* Oakland, *Brewer* no. 2764, *Holder* no. 2520; Berkeley, fresh material; Briones hills, Contra Costa co., *Chandler* no. 595; Bryants, Contra Costa co., *Chandler* no. 575; Moraga valley, Contra Costa co., *Hall* no. 1624; Mt. Diablo, *Chandler* no. 970; San Francisco, *Chandler, Davy* no. 2975, *Jepson*, etc.; Palo Alto, *Dudley;* Tres Pinos, *Dudley;* Pajaro hills, Monterey co., *Chandler* no. 410; Monterey, *Plaskett;* Pacific Grove, *Chandler;* San Luis Obispo co., *Brewer* no. 406, *Mabel M. Miles* no. 146; Santa Barbara, *Brandegee;* Santa Susanna mts., *Brewer* no. 216; Leonis valley, *Davy* no. 2610; Claremont, *Martha Allen, Chandler;* San Bernardino, *Parish* no. 25, *Setchell;* Gavilan, Riverside co., *Hall* no. 2931; Winchester, *Hall;* Temescal mts., *Hall* no. 406; San Jacinto, *Mrs. Gregory;* San Jacinto mts., *Hall;* Temecula, *Cleveland;* Banner, *Brandegee;*

Santa Ysabel, *Alderson;* San Felipe, *Brandegee;* Rosedale, *Abrams;* Lerdo, *Brandegee;* Tulare, *Davy* no. 3102; Kaweah, *R. Hopping* no. 166; Grapevine spring, Tulare co., *Woolsey;* Alcalde, *Brandegee;* Fresno, *Buckminster;* Yosemite, *Dodd;* Rose springs, El Dorado co., *M. H. Gates;* Sacramento, *M. S. Baker;* Penn valley, Nevada co., *Jepson;* Sutter co., *Jepson;* Chico, *Winifred Paine;* "California," *Thomas Bridges*, no. 170.

The type was collected in California by the botanists of the Beechey Voyage, all of whose collecting was done at San Francisco and Monterey. It is in the herbarium at the Royal Botanic Garden, Kew, and is said to have no flowers.[5]

8. N. MENZIESII **atomaria** (F. & M.) Chandler, comb. nov.—*N. atomaria* F. & M., Ind. Sem. Hort. Petrop. **2**: 42. 1835. *N. Menziesii* of Bot. Cal., Syn. Fl., etc., not of H. & A. *N. insignis atomaria* (F. & M.) Jepson, Fl. West. Mid. Cal. 434. 1901. *N. venosa* Jepson *l. c.* (a garden escape). *N. Johnsoni* Eastwood, Bull. Torr. Bot. Club **29**: 472. 1902.—More succulent and less pubescent than the type, often nearly glabrous: calyx-lobes shorter and broader: corolla rather smaller, somewhat more deeply divided, white or pale blue, dotted or rarely only veined dark blue-purple or black, hairy at the center; scales very narrow, usually hairy, scarcely or not at all enlarged or free at the tip, often reduced to a mere line of hairs.

Some authors find the style more deeply divided than in the type.

This variety intergrades with the type in every character and the variations are not always concomitant, so that there are frequently specimens (*e. g., Chandler* no. 1276, Humboldt co., Cal.) which may be referred almost equally well to either. Plants which in every other respect answer to var. *atomaria* (*e. g. Michener & Bioletti*, Sonoma, Cal.) have scales broader than is usual even in the type; while others which are plainly *N. Menziesii* (*e. g., Plaskett*, Monterey, Cal.) have the scales reduced to a mere line of hairs. Between these extremes there is every variation.

In a series of a half dozen living specimens from Kenwood, Cal., *M. S. Baker*, there were several instructive series. In color and marking of corolla three distinct steps were observed on as many plants: *A*, flowers white, dotted with blue to the edge; *B*, flowers slightly bluish, veined deeper blue, dotted toward the center; *C*, flowers bright blue, veined darker blue, white (but not dotted) at center. In the matter of succulence, a series of three plants showed a decided increase of pubescence and an approximately corresponding decrease of succulence as the type was approached. The shape of the calyx-lobes varied less uniformly.

[5] Bioletti, Erythea 3: 140.

A species is probably now being evolved in the direction of greater succulence, less pubescence, smaller and lighter-colored flowers, shorter calyx-lobes and narrower corolla-scales; but on account of the complete intergradations and the frequent lack of concomitance in variation, it seems best to retain the form as a variety. For this same reason *N. intermedia*, which lies between *N. Menziesii* and the variety, is excluded.

Most of the variegated garden Nemophilas should probably be referred to this variety.

COAST RANGES OF CALIFORNIA, IN MOIST PLACES.

Specimens examined: OREGON: Elk Head, Douglas co., *Howell.*

CALIFORNIA: Smith river, Del Norte co., *P. E. Goddard;* Hupa, Humbolt co., *Chandler, Davy & Blasdale* no. 5739, *Mrs. Manning;* Ukiah, *Purdy;* Round valley, Mendocino co., *Westerman;* Napa river basin, *Jepson;* Yountville, *Jepson;* Sonoma, *Michener & Bioletti;* Kenwood, *M. S. Baker;* Cloverdale, *Setchell;* Point Reyes, *Davy* no. 1684, *Eastwood;* Olema, *Davy* no. 681; Fairfax, *Michener & Bioletti;* Mt. Tamalpais, *Chandler* no. 485, *Jepson;* San Francisco, *Chandler*, etc.; San Mateo co., *Tidestrom;* Loma Prieta mt., *Davy* nos. 441, 541, and 604; Alma, Santa Cruz co., *Brandegee;* Glenwood, Santa Cruz co., *Michener & Bioletti.*

The type locality is "circa coloniam Ross in Nova California," near the present town of Fort Ross. The type specimen is doubtless in the herbarium of the Imperial Botanic Garden at St. Petersburg.

9. N. MENZIESII INTEGRIFOLIA Parish, Erythea **6**: 91. 1898.—*N. rotata* Eastwood, Bull. Torr. Bot. Club **28**: 159. 1901. excl. pl. *Orcutt.*—Plants slender, often prostrate: cotyledons with orbicular or oval blade: leaves usually (not always) somewhat less divided than in the type, sometimes even entire or with only a few lobes at the tip and a cuneately narrowing base: peduncles sometimes shorter than the leaves: flowers smaller than in the type: corolla pelviform to almost rotate, often only 1^{cm} across, pale blue or white, veined blue, usually hairy and dotted with purple toward the center; scales oblong to linear, half free or attached by one of the narrow edges, variously hairy or laciniate.

The leaves of this variety are infinitely various and a great range of shapes is often found on the same plant. The scales are also various, but almost never wholly adherent; the most common form seems to be a linear scale which is attached for half its length, then turns outward at an obtuse angle and comes to a bristly acuminate point.

The var. *integrifolia* is a southern analogue of the var. *atomaria*, from which it differs chiefly in less succulent habit, greater pubesence, shape of

cotyledons, less divided leaves, peculiar corolla-scales, and geographical range. Where the ranges of the two varieties meet they intergrade (Leonis valley, *Davy;* Casitas pass, *Hall*).

Of the variety as described here, the type specimen is an extreme form, having mostly entire leaves.

SOUTHERN CALIFORNIA.

Specimens examined: CALIFORNIA: Elizabeth lake, Los Angeles co., *Hall* no. 3081; Antelope valley, *Davy;* Leonis valley, *Davy;* Pasadena, *M. E. Jones;* Santa Monica, *Barber;* Claremont, *Illingworth, Sanborn;* San Bernardino mts., *Hall, Parish* no. 4196; Palomar, *Hall* no. 1951; Ramona, *Brandegee;* San Jacinto mts., *Hall* no. 2266; Encinitas, El Volcan, and Point Loma, San Diego co., *Brandegee;* Witch creek, San Diego co., *Alderson;* Laguna woods, San Diego co., *Cleveland;* San Diego, *Eastwood* (type of *N. rotata*).

The type locality is Waterman cañon, San Bernardino mountains, and the type specimen is in the herbarium of S. B. Parish, at San Bernardino.

10. N. SEPULTA Parish, Erythea **7**: 93. 1899.—*N. Menziesii minutiflora* Suksdorf, Deut. Bot. Monatsch. **18**: 133. 1900. *N. densa* Howell, Fl. N. W. Am. 466. (Mch. 21) 1901. *N. nana* Eastwood, Bull. Torr. Bot. Club **28**: 151 (Mch 27) 1901. *N. exigua* Eastwood, *l. c.* 157. *N. alata*, Eastwood, *l. c.* 158.—Plant prostrate, or very rarely sub-erect: branches from mostly a few centimeters to 4^{dm} long, sometimes winged, sparingly pubescent: cotyledons spatulate: leaves opposite, 2 to 5^{cm} long, oblong in outline, pinnate into 5 to 7 mostly oblong, rarely toothed divisions: peduncles shorter or longer than the leaves, strongly deflexed in age and sometimes burying the capsules: calyx-lobes lanceolate, 2 to 5^{mm} long; appendages from a third to three-fourths as long, spreading or reflexed: corolla open-campanulate, the lobes longer than the tube, 3 to 7^{mm} across, white, often dotted with blue toward the center; scales linear or reduced to hairy lines: style from once to twice as long as the ovary, divided for a third or a half its length: capsule globose, 3 to 6^{mm} in diameter: seeds usually about 4 per capsule, irregularly elongated-globose, 2 to 3^{mm} long, coarsely pitted and minutely scabrous (when typical), scaly; the caruncle cap-like. *Plate I.*

This species is very close to the succeeding and also shows affinity with

N. Menziesii. Field study is needed with reference to the shape and markings of the corolla.

FROM WASHINGTON TO SOUTHERN CALIFORNIA.

Specimens examined: WASHINGTON: Clark co., *Suksdorf* no. 2315; Klickitat co., *Suksdorf* nos. 684 and 2198 (co-type of *N. Menziesii minutiflora*).

OREGON: Mosier, Wasco co., *Howell;* Oregon city, *Howell;* Mitchell, Crook co., *Howell;* Prineville, Crook co., *Leiberg* no. 250; Ouryhee, Malheur co., *Leiberg* no. 2180.

CALIFORNIA: Little Shasta, Siskiyou co., *F. W. Hooper;* Forestdale and Pine creek, Modoc co. *M. S. Baker;* Clear creek, Butte co., *Brown* no. 173 (type of *N. alata*); Mohawk valley, Plumas co., *Lemmon;* Sierra valley, Sierra co., *Lemmon;* Stony creek, Amador co., *Hansen* no. 1522 (type of *N. exigua*); Bartlett mt., Lake co., *Eastwood* (type of *N. nana*); San Bernardino mts., *Parish* nos. 1842, 3782 (co-type), and 4908.

The type locality is Bear valley, San Bernardino mts., California, and the type is in the herbarium of Mr. S. B. Parish, at San Bernardino.

11. N. PEDUNCULATA Dougl., in Benth. Trans. Linn. Soc. **17**: 275. 1837.—*N. humifusa* Kellogg, in Eastwood, Bull. Torr. Bot. Club **28**: 41. 1901. *N. Austinae* Eastwood, *l. c.* 143.—Plant prostrate, in open places spreading in dense mats, or among underbrush decidedly lax: branches mostly 5 to 30^{cm} long, sparingly pubescent: cotyledons mostly with oval blade and narrow petiole: leaves opposite, 2 to 5^{cm} long (in rare cases 8^{cm} long), oblong (or rarely ovate) in outline, pinnate into 5 to 7 broad, usually toothed or lobed divisions: peduncles shorter (or sometimes longer) than the leaves, strongly deflexed in age and sometimes burying the capsules: calyx-lobes lanceolate, 1.5 to 4^{mm} long; appendages narrower, usually less than half as long, spreading or reflexed: corolla tubular or tubular-campanulate, the lobes about as long as the tube, scarcely exceeding the calyx, 2 to 3^{mm} across, white or pale blue; scales linear or reduced to hairy lines: style from once to twice as long as the ovary, divided for a third or a half its length: capsule globose, mostly 2 to 4^{mm} in diameter: seeds 2 to 12 (mostly 6 to 8) per capsule, elongated-globose, 1.5 to 2.5^{mm} long, coarsely pitted and minutely scabrous, scaly; caruncle cap-like, often having a narrow prolongation at one side. *Plate II.*

N. Austinae may prove distinct enough to become a variety. It is

marked chiefly by its often shallowly 5-lobed leaf, which is ovate in outline, and its few seeds (2 to 4 per capsule). The type came from Davis creek, Modoc county, California, *Mrs. Austin*, and specimens collected by the writer at Marble mountain, Siskiyou county, are similar. The form should be observed for other characters.

FROM WASHINGTON TO LOWER CALIFORNIA.

Specimens examined: WASHINGTON: Klickitat co., *Suksdorf* nos. 2637, 2638.

OREGON: Dalles city, *Suksdorf* no. 2639.

CALIFORNIA: Davis creek, Modoc co., *Austin* (type of *N. Austinae*); Marble mt., Siskiyou co., *Chandler* nos. 1649 and 1706: Susanville, Lassen co., *Brandegee;* San Francisco, *Kellogg* (type of *N. humifusa*), *Chandler* no. 1800; Coyote creek, Santa Clara co., *Chandler* no. 929; Island of Santa Cruz, *Brandegee;* Santa Inez mts., *Brandegee;* Porterville, Tulare co., *Dudley*.

LOWER CALIFORNIA: Japa valley, *Orcutt* no. 1128, in part.

The type locality is the Columbia river and the type specimens are in the herbarium of the Royal Botanic Gardens at Kew.

12. N. SPATULATA Coville, Bot. Death valley. 156. 1893.—*N. inconspicua* Eastwood, Bull. Torr. Bot. Club **28**: 144. 1901, not *N. inconspicua* Henderson. *N. pratensis* Eastwood, *ibid.* **29**: 474. 1902.—Closely related to *N. pedunculata*, but differing in the following particulars: leaves spatulate in outline, 3 to 5- toothed or -lobed only at the tip, with long cuneate base: corolla often with a purple spot at the tip of each lobe and a few dots at the center; scales small and laciniate or obsolete: style sometimes scarcely evident: seeds fewer (mostly 3 or 4) per capsule; caruncle cap-like, without a prolongation at one side.

The type specimen is itself an intergrade and dangerously near *N. pedunculata*. At the other extreme the variation is toward *N. maculata*, which it approaches in leaves and corolla markings.

SOUTHERN SIERRA NEVADA AND SAN JACINTO MOUNTAIN, CALIFORNIA.

Specimens examined: CALIFORNIA: Sierra Nevada mts., Fresno co., *Hall & Chandler* nos. 104, 411 and 423; Bearskin meadow, South fork King's river, *Eastwood* (type of *N. inconspicua* Eastwood); Sierra Nevada mts., Tulare co., *Death valley expedition* nos. 1522 and 1671 (type); San Jacinto mt., *Hall* no 2406.

"Type specimen in the United States National Herbarium, no. 1671,

Death valley expedition; collected August 21, 1891, in Whitney meadows, Sierra Nevada, Tulare co., California, by Frederick V. Coville."

13. N. PARVIFLORA Dougl., in Benth. Trans. Linn. Soc. **17**: 275. 1837.—*N. inconspicua* Henderson, Bull Torr. Bot. Club **27**: 349. 1900, not *N. inconspicua* Eastwood. *N. macrophylla* Eastwood, Bull. Torr. Bot. Club **28**: 144. 1901. *N. pustulata* Eastwood, *l. c.* 145. *N. micrantha* Eastwood, *l. c.* 146. *N. Kelloggii* Eastwood, *l. c.* 147. *N. Plaskettii*, Eastwood, *l. c.* 147.—Stems mostly weak, decumbent or ascending, 3 or 4^{cm} to as many decimeters long, hispid: cotyledons with orbicular or oval blade and long slender petiole: leaves mostly opposite, 1 to 6^{cm} long, various but typically ovate in outline, pinnately 5-lobed, the lobes toothed or lobed, the upper three often confluent, the lateral occasionally petiolulate: peduncles seldom as long as the leaves: calyx-lobes triangular or lanceolate, 1 to 4^{mm} long; appendages less than half as long, lanceolate, spreading: corolla mostly tubular-campanulate, 2 to 5^{mm} across, little exceeding the calyx, white or suffused with blue; scales minute, various but usually half free and ciliate or laciniate: style once to twice as long as the ovary, divided about half way: capsule globose, 3 to 5^{mm} in diameter: seeds usually 4 per capsule, but varying from 2 to 5, irregularly globose, deeply pitted and minutely roughened, scaly; caruncle stipe-like. *Plate III.*

FROM IDAHO AND WASHINGTON THROUGH OREGON AND THE COAST RANGES OF CALIFORNIA.

Specimens examined: BRITISH COLUMBIA: Vancouver, *Macoun* (type of *N. pustulata*).

IDAHO: Soldier mt., *Henderson* (type of *N. inconspicua* Henderson).

WASHINGTON: Whidby island, Puget sound, *Gardner* no. 395; Nesqually, Puget sound, *Wilkes Exped.*, no. 90; Seattle, *Piper;* upper valley of the Nesqually, *Allen* no. 61; Klickitat co., *Suksdorf* no. 172; "Washington Territory," *Dr. Cooper;* "Washington," *Brandegee.*

OREGON: Portland, *Henderson, Kellogg & Harford;* Polk co., *Spillman;* "Western Oregon," *Howell;* Sauvie's island, *Howell.*

CALIFORNIA: Sommes bar, Siskiyou co., *Chandler* no. 1537; Redwood creek, Humboldt co., *Chandler* no. 1270; Hydesville, Humboldt co., *Tracy;* Rowe's station, Mendocino co., *Chandler* no. 1037; Ukiah, *Purdy;* Mendocino, *Brown* no. 742; Inverness, Marin co., *Eastwood;* Mt. Tamalpais,

Chandler nos. 515, 769, etc., *Eastwood* (type of *N. micrantha*); San Mateo co., *Kellogg & Brannan*; Wrights, Santa Cruz co., *Brandegee*; Big basin, Santa Cruz mts., *Dudley*; Santa Cruz mts., *Kellogg & McLean* (type of *N. Kelloggii*); Santa Lucia mts., Monterey co., *Plaskett* no. 32 (type of *N. Plaskettii*); "California," *Vasey*.

The type locality is the Columbia river and the type specimen is in the herbarium at the Royal Gardens, Kew.

14. N. PARVIFLORA **quercifolia** (Eastwood) Chandler, comb. nov.—*N. quercifolia* Eastwood, Bull. Torr. Bot. Club **28**:142. 1901.—Plant with softer, more spreading pubescence than the type: leaves with more rounded lobes and shallower sinuses, the lower of these scarcely deeper than the upper: peduncles mostly exceeding the leaves: calyx-lobes mostly oblong.

This variety is separated on what are usually rather unstable characters, but here they seem constant enough to warrant a separation, especially since the geographical range is quite remote from that of the type.

FOOTHILLS OF THE SOUTHERN SIERRA NEVADA.

Specimens examined: CALIFORNIA: Pine ridge, Fresno co., *Hall & Chandler* nos. 91 and 250; Sequoia mills, Fresno co., *Eastwood* (type); Kernville, *Brandegee*; Greenhorn mts., Kern co., *Palmer* no. 32; San Emidio cañon, Kern co., *Davy* no. 2070.

Type in the herbarium of the California Academy of Sciences, San Francisco; collected at Sequoia mills, Fresno co., by Alice Eastwood.

15. N. MICROCALYX (Nutt.) F. & M.—*Ellisia microcalyx* Nutt., Trans. Am. Phil. Soc. II. **5**: 191. 1833–7. *E. ranunculacea* Nutt., *l. c.* *Nemophila microcalyx* F. & M. Sert. Petrop. *t. 8*. 1846.—Near *N. parviflora*, but differing principally in the following particulars: leaves broader at the base, often only 3-parted, mostly alternate: peduncles shorter: corolla-scales often obsolete: seeds usually only 1 or 2 per capsule.

SOUTHERN UNITED STATES, FROM VIRGINIA AND FLORIDA WESTWARD TO ARKANSAS AND TEXAS.

Specimens examined: TENNESSEE: Knoxville, *Ruth*; Nashville, *A. H. Curtiss* no. 2125, *Gattinger*.

ARKANSAS: Little Rock, *Hasse*.

LOUISIANA: St. Martinsville, *Langlois*.

Type locality, "Arkansas, Alabama, etc."

16. N. BREVIFLORA Gray, Proc. Am. Acad. **10**: 315. 1875.—*N. parviflora* of Torr. in Wats. Bot. King Exp. 249, excl. char.—

Plant usually weak, though often fleshy: branches decumbent or ascending, 5 to 35^{cm} long, sparingly hairy: cotyledons spatulate: leaves (all but the lowest) alternate, 2 to 5^{cm} long, triangular-ovate in outline, deeply pinnately parted into mostly 5 oblong, falcate, entire or 1 or 2-toothed divisions: peduncles shorter than the leaves: calyx-lobes oblong- to linear-lanceolate, 2 to 5^{mm} long in flower, enlarging greatly in fruit, nearly or quite glabrous except for the strongly ciliate margins; appendages proportionately broader, less than half as long, reflexed: corolla mostly tubular, not exceeding the calyx, about 2^{mm} across, white or purplish; scales narrow, trapeziform, fimbriate: style scarcely longer than the ovary, cleft only at the tip: capsule globular, 3 to 5^{mm} in diameter: seeds 1 per capsule, globular, 2 to 3.5^{mm} in diameter, pitted and minutely roughened, scaly, often blood-red; caruncle cap-like (?), evanescent.

ROCKY MOUNTAINS FROM UTAH TO MONTANA AND WESTWARD TO WASHINGTON AND OREGON. Not yet found in California, but to be looked for in Modoc and Siskiyou counties.

Specimens examined: WASHINGTON: Yakima region, *Brandegee;* Falcon valley, *Suksdorf;* "Washington," *Vasey* no. 403.

OREGON: Blue mts., *Coville* no. 537, *Howell;* eastern Oregon, *Cusick;* Steins mts., *Leiberg* no. 2498.

MONTANA: Summit G. N. Ry., *Williams* no. 170; Bridger mts., *Rydberg & Bessey* no. 4860.

IDAHO: Coeur d'Alene mts., *Leiberg* no. 1062; Latah co., *Piper;* Craig mts., *Henderson* no. 2748.

WYOMING: Yellowstone park, *Nelson* no. 5566, *Tweedy* no. 405; Teton forest reservation, *Brandegee.*

UTAH: Bear river cañon, *Watson* (*King exped.*) no. 869 (type).

The type was collected at Bear river cañon, Utah, July, 1869, by Sereno Watson, as no. 869 of the Clarence King expedition, and was determined by Torrey (not by Watson, as Gray implies in his citations) as *N. parviflora.* It is in the United States National Herbarium.

17. N. EXILIS Eastwood, Bull. Torr. Bot. Club **28**: 148. 1901. —*N. flaccida* Eastwood, *l. c.* 149. *N. inaequalis* Eastwood, *l. c.* 149. *N. hispida* Eastwood, *l. c.* 152. *N. divaricata* Eastwood, *l. c.* 153. *N. tenera* Eastwood, *l. c.* 153. *N. gracilis* Eastwood, *l. c.* 154. *N. nemorensis* Eastwood, *l. c.* 155. *N. glauca* East-

wood, *l. c.* 156. *N. fallax* Eastwood, *l. c.* 156. *N. diversifolia* Eastwood, *ibid.* **29**: 473. 1902. *N. decumbens* Eastwood, *l. c.*— Plants when growing in deep shade weak and only moderately hairy; in more open places usually more stout and hispid: branches from a few centimeters to 6^{dm} long: cotyledons with orbicular or oval blade and slender petiole: leaves exceedingly diverse in form and size, 1 to 10^{cm} long; the lower opposite, mostly pinnate with 5 to 9 suborbicular, often 2 or 3-lobed divisions on narrow petiolules; the upper often alternate, less divided, not rarely entire: peduncles slender, shorter or longer than the leaves, spreading: calyx-lobes from ovate- to linear-lanceolate, 1.5 to 5^{mm} long; appendages proportionately broader, mostly less than a fourth as long, reflexed: corolla pelviform or broadly campanulate, 4 to 10^{mm} across, white or bluish; scales various, semicircular, oblong or triangular, occasionally half free, entire or laciniate: style from 1 to 3 times as long as the ovary, parted for from a third to a half its length: capsule globular, 2 to 4^{mm} in diameter: seeds 2 to 5 per capsule, elongated-globular, scrobiculate; caruncle cap- or stipe-like. *Plate IV.*

This species includes several forms which have long been classed with *N. parviflora.* It represents a larger range of variation than any other Nemophila, but these variations are nearly all directly referable to life relations. In view of the attempt which has recently been made[6] to define several species in this group, a discussion of the characters employed in discrimination of the forms seems worth while.

Habit, pubescence, and leaves do not afford satisfactory characters, for they all depend to a great extent on the life relations of the individual. For example, plants growing in deep shade tend to produce broad leaves and sparse pubescence, the degree of dissection of the leaves and the density of the pubescence being fairly accurate measures of the intensity of the light received; moisture very strongly increases the general thrift of the plant and diminishes the pubescence; competition prevents spreading and lengthens the internodes; so, too, soil, temperature, wind, and a dozen other factors have their influences. When we remember that not one, but all of these factors are operative on each plant, and when we realize that we are dealing with one of the most unstable of genera, we are constrained to put little faith in vegetative characters.

[6] EASTWOOD, Bull. Torr. Bot. Club **28**: 137 *et seq.*

Miss Eastwood has divided the small-flowered Nemophilas into eight groups based upon the shapes of the corolla. These distinctions are too fine. Such factors as age, the time of day, the degree of shade, or the amount of nourishment received by the individual plant may easily make great differences in the appearance of pressed flowers. For example, in the morning a plant may appear to have tubular flowers, while in the afternoon, when the light is more intense, the same flowers may open wider and become tubular-campanulate. If pressed in the morning condition, the flowers even when soaked up will appear tubular, and correspondingly for those pressed in the afternoon condition. As an instance of how dangerous such a close division on this line may be, witness that Miss Eastwood has placed *N. sepulta* in Section 1, "Corolla tubular, minute," when that species almost invariably has open-campanulate flowers.

The position of the corolla-scales is also unreliable. In the living flowers of most species the scales stand nearly perpendicular to the corolla; so their position in the pressed flower is accidental, or at most represents a very slight inclination from the perpendicular in the living flower. One frequently finds in the same flower some scales folded towards the stamens and others folded away from them; so that in most cases very little significance can be attached to their position.

The shape of the scales is also exceedingly diverse, apparently much more so than in the large-flowered species. Plants which agree in every other particular often show quite different scales, and there is sometimes considerable variety on one plant or even in one flower.

The writer has found no character which seems perfectly satisfactory for discriminating species. In so variable a genus as Nemophila, and more particularly in this most variable group, concomitance in variation should be demanded before a form is named; otherwise there is no limit to the number of species we may make and our classification will become a burden. Some of the species here reduced may prove to present such concomitance when they are better known; but at present the writer does not feel justified in maintaining them.

Unfortunately, the type specimen of *N. exilis* is not a typical form of the species as here described. The writer does not find the corollas of the type "distinctly salverform," and he inclines to the opinion that their approximation to that form is due to the flowers shriveling before being pressed. Flowers of even so open-flowered a species as *N. Menziesii* have been seen where this had occurred with a similar result. If this character should prove to have value, however, and if it can be connected with other characters, the remaining forms should be separated as variety *flaccida*. *Plate IV* represents the form published as *N. nemorensis*, which is the most common one about San Francisco bay, and which is taken as typical of the group of forms which make up the species.

It is perhaps worthy of note that the leaves which are least divided are most often alternate. This tendency is shown on very many specimens, and is extreme in the forms separated as *N. flaccida* and *N. inaequalis*.

FROM SOUTHERN OREGON THROUGH NORTHERN AND CENTRAL CALIFORNIA.

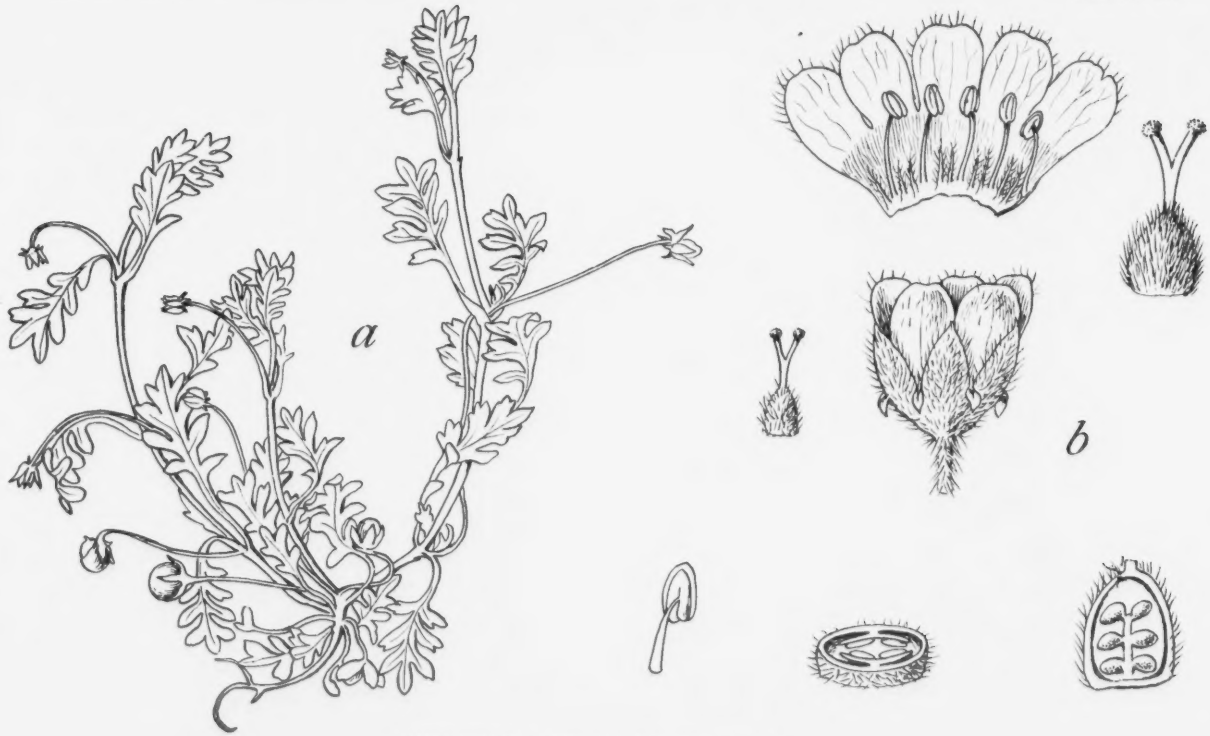
Specimens examined: OREGON: Rogue river valley, *Howell*.

CALIFORNIA: Hupa, Humboldt co., *Mrs. Manning;* Mendocino co., *Bolander* no. 4647, *Brandegee*, *Chandler* nos. 1035 and 1065, *Eastwood*, *Purdy*, *Westerman;* Solano co., *Setchell;* Napa co., *Jepson;* Rutherford, *Chandler* no. 630; Sonoma co., *M. S. Baker*, *Bolander* nos. 3802 and 3811, *Samuels* no. 174; Windsor, *Mrs. Swett;* between Clear lake and Bartlett springs, *Eastwood* (type of *N. hispida*); Mt. St. Helena, *Eastwood* (type of *N. divaricata*); Russian river, *Brandegee* (type of *N. inaequalis*); Marin co., *Brewer* no 938; Fairfax, *Eastwood* (type of *N. nemorensis*), *Michener & Bioletti;* Mt. Tamalpais, *Chandler* nos. 256, 768, etc., *Davy* no. 143, *Eastwood*, *Michener & Bioletti* etc.; Sausalito, *Kellogg & Harford* no. 785; Angel island, San Francisco bay, *Davy* no. 6885, *McLean*, *Michener & Bioletti;* Berkeley, *Chandler* nos. 554, 567, 1802, 1803, 1804, etc., *Davy* nos. 6920, 6922, etc., *Greene*, *Hall*, etc., and fresh material; Oakland, *Chestnut*, *Holder* no. 2589; Moraga valley, Contra Costa co., *Hall* no. 1625; Mt. Diablo, *Chandler* nos. 948, 949, and 985; Briones valley, Contra Costa co., *Chandler* nos. 580 and 580A; Antioch, *Davy* nos. 907 and 916; Martinez, *Chandler* no. 850; Stanford University, *Dudley*, *Rutter* no. 6; Loma Prieta mt., Santa Clara co., *Davy* no. 72a; Evergreen, Santa Clara co., *Davy* nos. 532 and 608; Pitt river, Shasta co., *Brown* no. 261 (type of *N. flaccida*); Iron cañon, Butte co., *Mrs. Austin* no. 272; Chico, *Winifred Paine;* Big Chico creek, *Austin* no. 2037 (types of both *N. glauca* and *N. fallax*); Stites, Colusa co., *Brandegee;* Applegate, Placer co., *Helen Smith* (type of *N. tenera*); Stockton, *Sanford;* Rose springs, Eldorado co., *Gates;* Amador co., *Hansen* nos. 1377 and 2064; Gwin mine, Calaveras co., *Jepson* no. 1785; Milton, Calaveras co., *Davy* no. 1390; Yosemite, *Bolander* no. 4820; Fresno, *Buckminster* (type of *N. gracilis*); Kaweah, *Hopping* no. 8; Grapevine spring, Tulare co., *Woolsey;* "California," *Bigelow* (*Whipple expedition*).

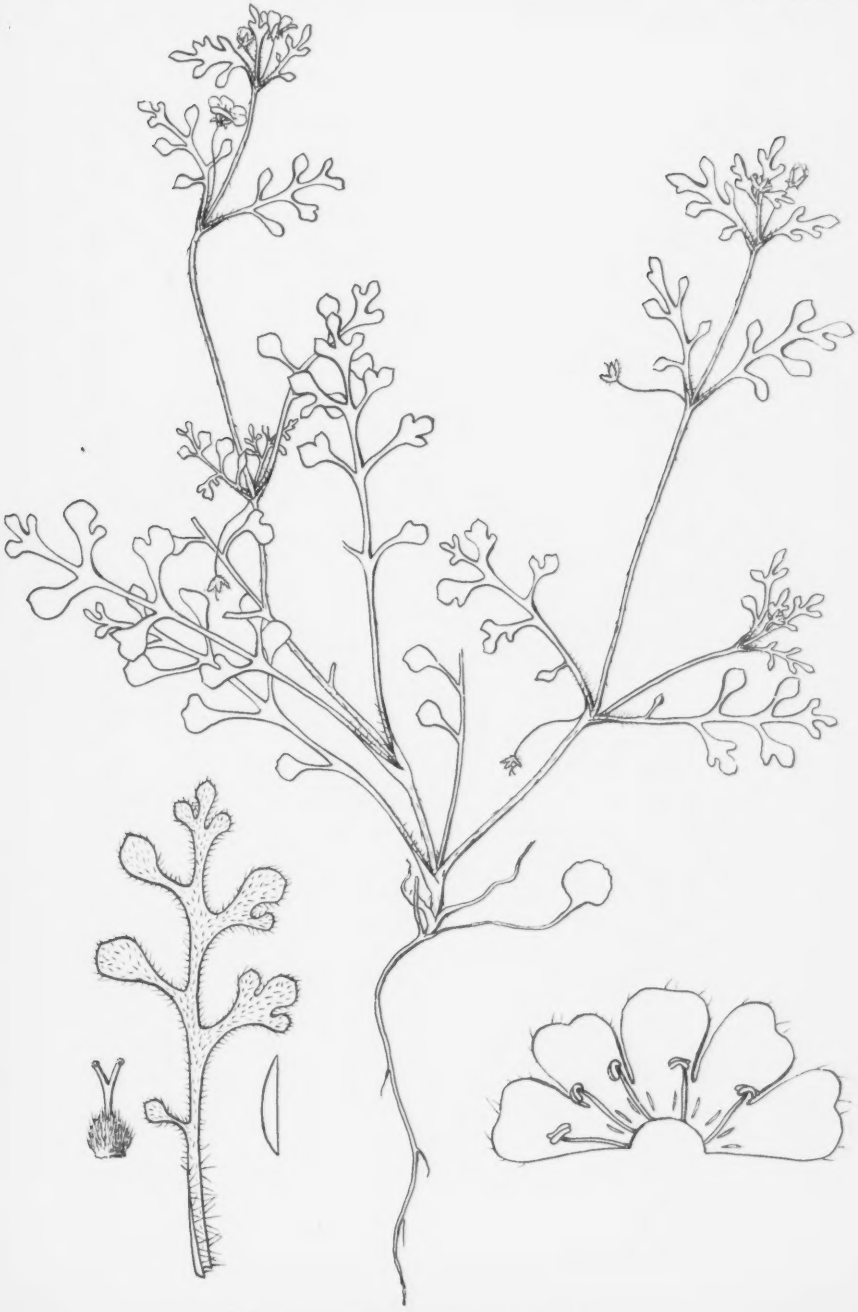
Type in the herbarium of the California Academy of Sciences, San Francisco; collected "on the Hog ranch road, Tuolumne county, California, by J. W. Congdon, June 9, 1897."

18. N. EXILIS **pulchella** (Eastwood) Chandler, comb. nov.—*N. pulchella* Eastwood, Bull. Torr. Bot. Club 28: 157. 1901.—Calyx-lobes linear, extending almost to the base; the appendages very minute or more often entirely wanting: corolla rotate-campanulate, mostly deep blue; scales linear, ciliate.

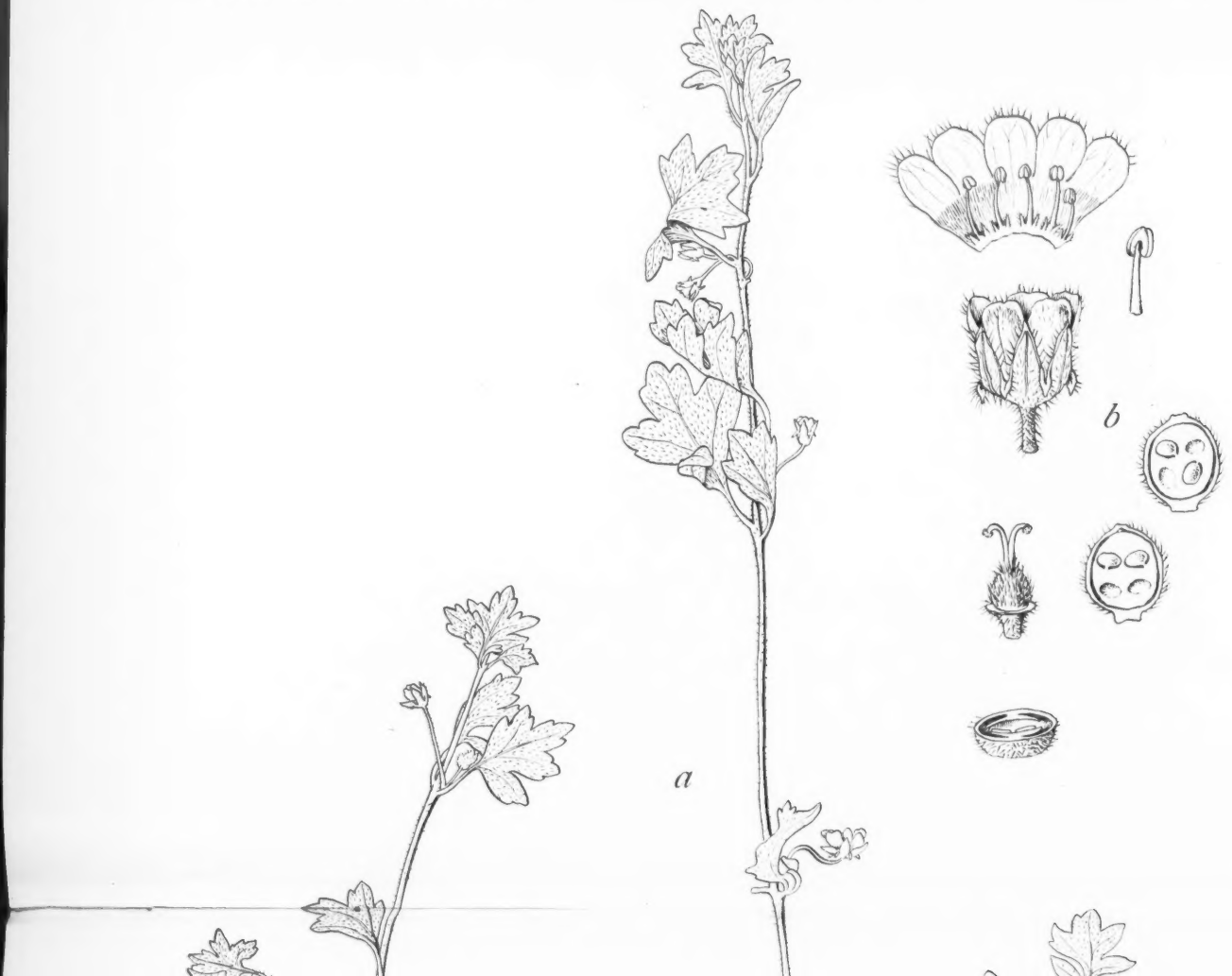
NEMOPHILA SEPULTA Parish

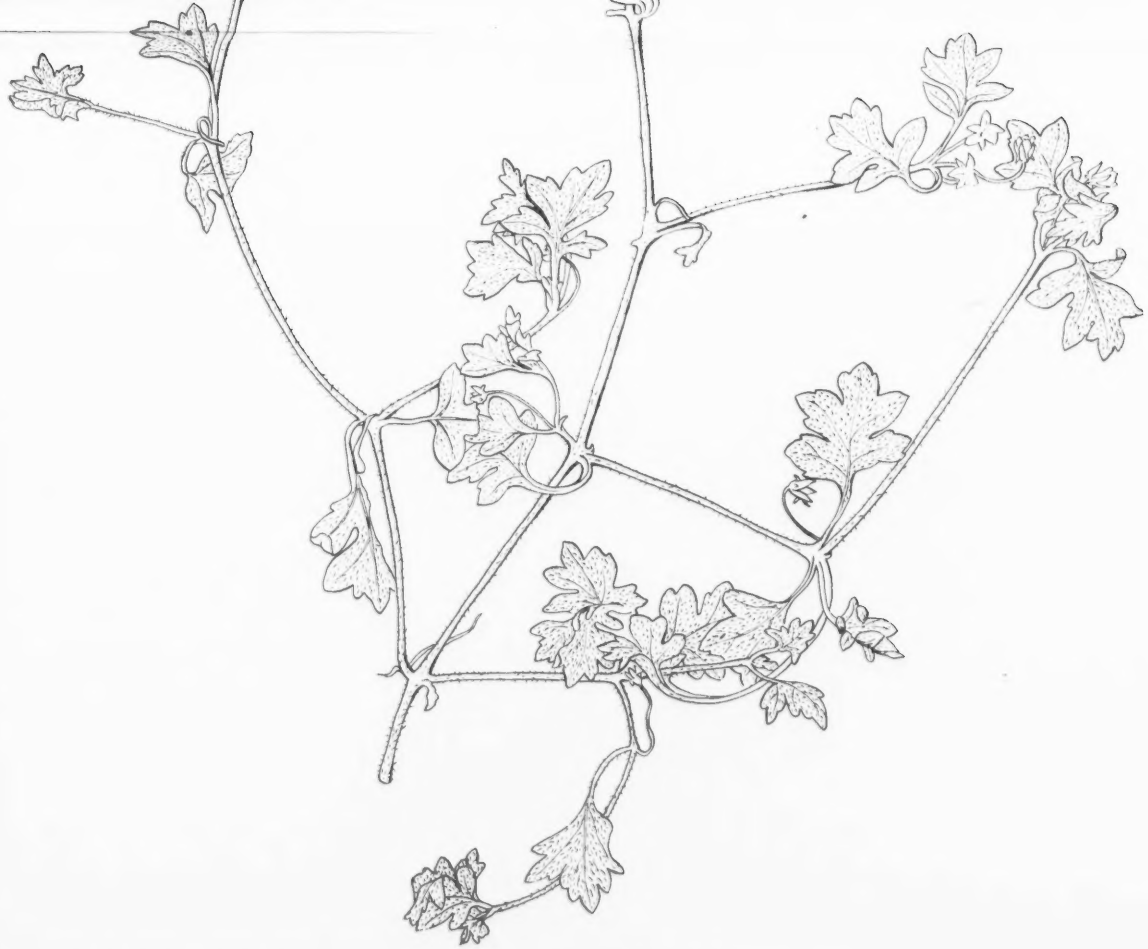


NEMOPHILA PEDUNCULATA Dougl.



NEMOPHILA PARVIFLORA Dougl.


a
b



NEMOPHILA EXILIS Eastwood

FOOTHILLS OF THE SOUTHERN SIERRA NEVADA.

Specimens examined: CALIFORNIA: Fresno co., *Eastwood, Eisen;* Sequoia park, *Jepson* no. 622; Kaweah, *Hopping* no. 37; Fraser's mill, Tulare co., (?) *Brandegee;* Salt creek, Tulare co., *Eastwood* (type); Cramer, Tulare co., *Brandegee;* Bear creek, Tulare co., *Purpus* no. 1720.

Type in the herbarium of the California Academy of Sciences, San Francisco; collected by Alice Eastwood on Salt creek, Tulare county, California.

UNIVERSITY OF CALIFORNIA.

EXPLANATION OF PLATES II–V.

Plate II. Nemophila sepulta Parish.

Specimen from the type locality (Parish no. 4908); natural size.

Plate III. Nemophila pedunculata Dougl.

A. Portion of the type; natural size.

B. Analysis, drawn from a plant collected by Dr. Thomas Coulter in California (no. 480).

Plate IV. Nemophila parviflora Dougl.

A. Type specimen; three-fourths natural size.

B. Analysis, drawn from a specimen in the herbarium at Kew.

Plate V. Nemophila exilis Eastwood.

Specimen from Berkeley, California (typical of the species, of which the type specimen is regarded as an extreme form); natural size.

THE EVOLUTION OF THE VASCULAR TISSUE OF PLANTS.

W. C. WORSDELL.

(WITH SEVEN FIGURES)

IT is a sign of the times and of the natural progress which botanical science is making that the evolution of the more deeply seated part of the organization of plants is beginning to receive attention. The most vital and important part of the anatomical structure is doubtless that of the vascular system, and it is the development of this upward through some of the most important groups of plants of which I propose to take a general survey.

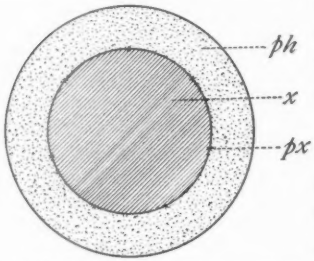


FIG. 1.—The protostele: *x*, xylem; *px*, protoxylem; *ph*, phloem.

We appear to be justified in looking for the primary origin of the complex vascular structure of the stems of cormophytes in the single *solid stele*, the *protostele*, consisting of a central mass of wood, or xylem, surrounded by a zone of bast, or phloem (*fig 1*), this in its turn having been derived from the primitive conductive tissue of the sporophytic stem of some bryophytic ancestor. If we take the great group of the ferns this structure always appears as the first stage in the individual development of each type, as has been shown by the researches of Leclerc du Sablon[1] and others. This is also the type found in the mature vascular structure of several of the most primitive ferns, such as the Hymenophyllaceae, Lygodium (Schizaeaceae), and Gleichenia, among modern forms, and Botryopteris among fossils.

[1] SABLON, LECLERC DU, Recherches sur la Tige des Fougères. Ann. Sci. Nat. Bot. VII. 11: —. 1890.

The next stage in general evolution, as the writer holds, is that in which a *pith arises in the center of the solid stele* (*fig. 2.*), on the outer limit of which an endodermis, or starch-sheath, may or may not be present; this is seen in such forms as Platyzoma (Gleicheniaceae,) Schizaea, the Ophioglossaceae, and in the fossils Zygopteris and Anachoropteris (Botryopterideae). The possibility, however, of these forms having been *reduced* from type 3 is not excluded. In all these ferns the protoxylem, or first-formed portion of the wood, is either situated within the metaxylem, or later-formed portion, a short distance from the periphery, or else, as in Lygodium, quite at the periphery; that is to say, the xylem is chiefly *centripetal* in its development.

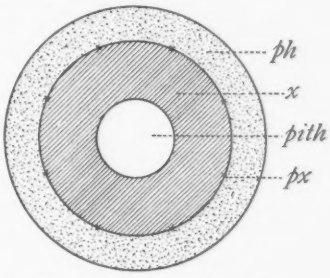


FIG. 2.— The tubular stele with central pith: *x*, *px*, *ph*, as in *fig. 1*.

The *solenostele* is the name given to the third stage of differentiation, in which to the internal endodermis is added an *internal zone of phloem* (*fig. 3.*); this is found in Matonia, Loxsoma, *Aneimia Mexicana* (Schizaeaceae), and in a few other plants, such as *Medullosa stellata* among the Cycadofilices.

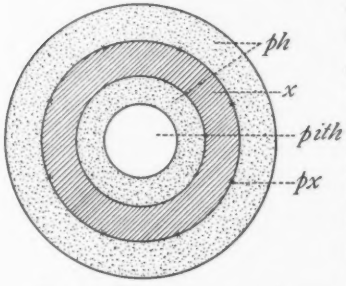


FIG. 3.— The solenostele: reference letters as before.

The *dialystelic* condition appears to have been the next step onward, in which the tubular solenostele becomes split up into a number of secondary solid steles or *concentric* strands (*fig. 4*), the protoxylem, as in the previous stages, being situated at or near the external limits of the xylem. This structure is directly due to the crowded arrangement of the leaves on the stem, so that frequent gaps in the original solenostele become inevitable in order to allow of the passing out of the leaf-trace

bundles; the whole is thus merely a variant on the solenostele, in which latter the leaf-insertions are not crowded; both conditions belong essentially, as Jeffrey[2] has admirably shown, to the *siphonostelic*, or tubular type of stele. Van Tieghem[3] was therefore in error in regarding the dialystelic condition as derived merely from branching of the primitive solid stele. Dialystely is very common in ferns, occurring in Marattiaceae, *Aneimia Phyllitidis* (Schizaeaceae), Cyatheaceae, Dicksoniae, and in almost all Polypodiaceae, the most advanced of the fern series. The vascular cylinders of *Osmunda regalis* and *O. cinnamomea* probably represent, as Jeffrey[4] has recently suggested, *reduced* forms, in a greater and a less degree respectively, of the dialystelic condition. It is also found in several of the Cycadofilices, the group intermediate between ferns and cycads, such as the Medulloseae and Cladoxylon, all fossil types.

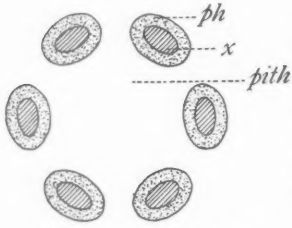


FIG. 4.— The dialystelic condition.

If we now take these last named *polystelic* plants as our starting point, we may trace from them the origin and evolution of the vascular tissue of the gymnosperms. The modification which eventually produced this latter consisted, as the writer, along with Potonié,[5] holds, in the gradual reduction of the concentric type of bundle or stele to form the first and simplest *collateral* type. In a form like *Medullosa anglica* there is a single ring of concentric steles. The theory which the writer regards as best explaining the facts is this: in order that it might give rise to the next succeeding type, as he regards it, represented by such forms as the fossil Cycadofilices, *Lyginodendron Old-*

[2] JEFFREY, E. C., Trans. Brit. Assoc. Adv. Sci. 869. 1897; Mem. Bost. Soc. Nat. Hist. V. 5: 160.

[3] VAN TIEGHEM, PH., Sur la Polystélie. Ann. Sci. Nat. Bot. VII. 3: —. 1886; Traité de Botanique, p. 1370. 1892.

[4] JEFFREY, E. C., The structure and development of the stem in pteridophytes and gymnosperms. Phil. Trans. Roy. Soc. June 1902.

[5] POTONIÉ, Lehrbuch Pflanzenpalaeontologie, 1899.

hamium, Poroxylon, and others, each concentric stele composing the cylinder of Medullosa underwent a reduction of the tissue on its inner side, whereby the phloem and the whole of the secondary wood of that side vanished, leaving behind what is known as a *mesarch* bundle, consisting of a central or an external protoxylem, with a group of primary metaxylem on both its inner and outer side, or solely in the former region; as a rule, a greater or less development of secondary wood and phloem occurs on the outer side of each bundle. The secondary wood usually extends across the gaps separating the bundles, to form a continuous solid cylinder enclosing a pith, thus tending eminently to obscure the original and primitive condition of a ring of reduced concentric strands (*fig. 5*). That these latter are each of them really a vestige of a concentric bundle, such as that of Medullosa, is shown very well in the case of *Lyginodendron Oldhamium* by the arc- or horseshoe-shaped outline of the bundles, as also by the occasional occurrence of secondary xylem and phloem on the *inner* side of some of the bundles, exhibiting an *inverted orientation*, as if to remind us that the concentric is the original type of structure of these strands. Dr. D. H. Scott[6] supposes that the stem cylinder of Lyginodendron has been derived from the single solid stele of Heterangium (another of the Cycadofilices from the Coal-measures), by means of the extinction of the whole of its central solid xylem with the exception of the primary tracheides on the immediate inner side of each protoxylem group. But the writer fails to see much ground for holding this view. The very compact stele of Heterangium, with the neatly and evenly circular outline of the inner limits

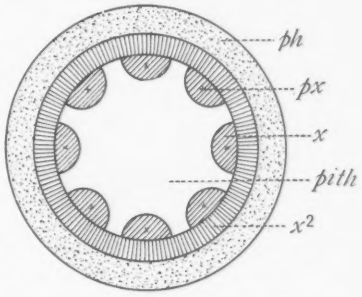


FIG. 5.—The primitive mesarch type: reference letters as before; x^2, secondary xylem.

[6] SCOTT, D. H., Studies in fossil botany, p. 340, 1900.

of the secondary wood, exhibits no sign whatever of having given rise to the more or less distinctly individualized curved bundles of the cylinder of *Lyginodendron Oldhamium*. The writer, on the contrary, believes it to be the homologue of a single stele of Medullosa, and can trace a gradual reduction in the number of steles in these plants, from the very numerous ones of *Medullosa Solmsii*, firstly, to the very few steles (two or three in number) of *M. anglica* or Colpoxylon, and finally, to the single large stele of Heterangium or of Megaloxylon. He may add, moreover, that the derivation of the tubular from the solid stele is to be sought for, not in these semi-gymnospermous forms, but much farther back, viz., among the ferns.

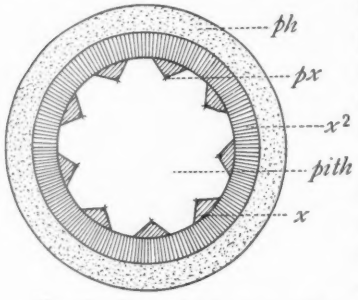


FIG. 6.—The endarch type: reference letters as before.

When we arrive at the stage of our modern cycads, which are certainly descended from some of these cycadofilicinean plants, a further modification meets our eyes, for here we find the mesarch bundle of the stem cylinder almost entirely replaced by the *endarch* type, in which the innermost primary or centripetal group of xylem has vanished, so that the protoxylem which, once upon a time in the ancient concentric bundle, occupied the center of the latter, now constitutes the most internal portion of the bundle, viz., that nearest the pith (*fig. 6*). But the older mesarch bundle has not become completely extinct throughout the group, for in that most primitive of axial organs, the peduncle of the cone, the centripetal xylem in part persists, as can be well seen in Stangeria and Bowenia. Those cycads, such as Cycas, Encephalartos, Macrozamia, and Bowenia, which possess more than one vascular cylinder in the stem, one within another to the number sometimes of a dozen (a truly striking character), are descended from such types as those Medulloseae having more than one cylinder or ring of concentric bundles,

as has been practically proved by the occurrence of obvious vestiges of the concentric type of structure, such as prevails among the Medulloseae, both in the vegetative stems and in the peduncles of all the pluricylindric forms of modern cycads.

In the Coniferae, from the yew tribe upward to the pines, as also in the Gnetaceae, all trace of the primitive mesarch type of bundle has disappeared from the stem, and we find the endarch type, with protoxylem impinging directly on the pith, universally prevailing. That ancient Devonian and Carboniferous plant, Cordaites, and our modern maidenhair tree, *Ginkgo biloba*, assumed also, in accordance probably with the exigencies of their arboreal habit, the endarch type of bundles in the stem. But *Pitys antiqua*, *P. primaeva*, *Calamopitys fasciculatis*, *C. beinertiana*, and *Dadoxylon Spenceri*, forms perhaps allied to Cordaites, still retain the older mesarch type.[7]

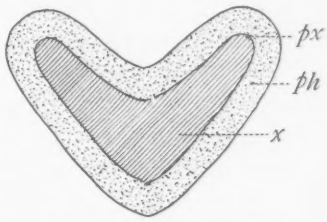


FIG. 7.—Concentric bundle of leaf-stalks.

As regards the foliar organs of all of these plants we have been considering, it is found that the primitive character of the vascular structure is in them much more persistent than it is in the stem. The concentric fern-type of bundle is still present in the leaf-stalks of Lyginodendron (Rachiopteris) and Heterangium, that of the former plant consisting of a solid stele with three or more protoxylem groups at its periphery, the whole being surrounded by phloem (*fig.* 7). In Medullosa, Cordaites, and modern cycads the bundles of the leaves are collateral and mesarch in structure; as are also those of the foliage leaves of conifers, although here the centripetal primary xylem is either greatly reduced or modified to form a quasi-new structure, the *transfusion tissue*. In Ginkgo this reduction also obtains in the foliage leaf. But in the most primitive vegetative foliar organs of the plant, the cotyledons, both in Ginkgo and Cephalotaxus (the

[7] SCOTT, D. H., On the primary structure of certain palaeozoic stems with the Dadoxylon type of wood. Trans. Roy. Soc. Edinburgh **40**: [pt. II]. 1902.

most ancient of the conifer group), the mesarch structure of the bundle is as pronounced and well developed as it is in the case of the cycads or Medulloseae. As regards these two latter groups, the writer regards their mesarch bundles as derived from the splitting up of one or more concentric bundles like that of Lyginodendron. In any case the mesarch collateral bundles of the foliar organs of all these plants are to be regarded, like those of the stem, as reductions from the concentric type. But this concentric type actually occurs here and there in the sporophylls of the cycads.

On arriving at the level of the angiospermous plants, all trace of any vestige of the old concentric type of bundle in the form of a mesarch structure has completely vanished both in the stem and in the leaf, the purely endarch structure prevailing everywhere. The fact of this type of structure occurring well-nigh universally in these plants which, in other parts of their organization, are seen to be the most advanced in evolution of all plants, is an indication that this type of vascular structure is also to be regarded as the most advanced, because the most advantageous and the best adapted to the requirements of the plants exhibiting it. The writer, however, considers that the conclusions drawn by Jeffrey, from the study of the vascular cryptogams, as to the origin of the vascular tissue of the stem are rather too hastily applied to the case of the angiosperms. We are not yet in a position to say whence the vascular system of these latter plants was derived. All we dare surmise is that, looking far enough back, it is probable that the vascular tissue of the angiosperms had an origin similar to that of the forms below them in the scale.

The cause of the disappearance of the primitive mesarch structure can be seen in tracing the evolution of the vascular tissue from such forms as the Medulloseae upward. Obviously, the most economical method of increasing the amount of vascular tissue for purposes both of conduction of water and food substances and of resistance to bending strains would be by the addition, through the means of a cambium, of new tissue on the *outer circumference* of the stele or cylinder; now, in pro-

portion as the tissue in this region increased in thickness, there took place, correlatively therewith (what, indeed, would be, *a priori*, obviously expected) a gradual reduction of the centripetal vascular tissue, viz., that on the medullary side of the protoxylem, whether secondary or primary. This can be seen beautifully exhibited within the Medulloseae group itself, eventually culminating in the stem structure of modern cycads. The process of elimination of the centripetal xylem proceeded apace, until finally the endarch stem structure of Cycads, Coniferae, Cordaites, Gnetaceae, and Dicotyledons, as being by far the most economical and advantageous method of vascular formation, eventually prevailed.

In the case of leaves there has not been such a demand for modification of the vascular tissues as was the case with the stem, hence the longer persistence of the older character in these organs.

In roots the primitive centripetal structure of the wood has been far more persistent, probably for the purpose of enabling these organs to resist central tension strains.

In Monocotyledons, although true secondary thickening does not occur, the endarch type of bundle nevertheless obtains; where the concentric structure is found, as in those cases of bundles with a central phloem, this is merely to be regarded as a modification of the endarch type.

KEW, SURREY, ENGLAND.

BRIEFER ARTICLES.

SUGGESTIONS ON THE CLASSIFICATION OF SEEDS.

MODERN botanical text-books do not present a classification of seeds in accordance with modern ideas of their structure and function. It comes as a distinct surprise to the average student of plants when he, for the first time, appreciates that some familiar herb, shrub, or tree may bear during a single season a score or more different types of seeds. Nor does the great complexity underlying the concept of the seed seem to be fully comprehended by the plant breeders and seed growers. Indeed, no method has been devised for recognizing the types of seeds that theoretically exist, nor, so far as I am informed, has a nomenclature been provided by which one type may be delimited from another. Under these circumstances it seems desirable to set down a simple classification of the more fundamental types of seeds in the hope that future experiment will indicate marks by which they may be recognized, and that some new light may thus be thrown upon the problems of hybridization, seed control, variation, mutation, and evolution of varieties and species.

To define the word "seed" in a manner technically accurate is exceedingly difficult. Underneath the seed lie the following conditions, in the absence of any of which the seed does not exist as such:

1. Alternation of generations. No seed is ever produced by non-alternating types of plants.

2. Heterospory. Among alternating types seeds are not produced by homosporous forms.

3. Intraspecific symbiose. Heterosporous types devoid of intergenerational symbiosis do not produce seeds.

The seed is in no exact sense an organ of the plant that bears it; it is rather an aggregate in the family life of the species. In it tissues and structures belonging to three consecutive generations are uniformly present either transitorily or permanently. While its significance for the persistence of the species may be very great, it cannot be

regarded as a reproductive organ in the sense in which an antheridium, archegonium, or sporangium is so regarded.

A common definition of the seed describes it as a "ripened ovule." The full value of this is appreciated when one finds the ovule defined as an "immature seed." Seeds, however, occur in plants destitute of ovules, in the ordinary sense, and in any event a thorough definition is desirable. The following statement covers, to some degree, the modern concept of the seed: "A seed is an ultimate, trigenerational, symbiotic unit in the plant life-history, integrated from tissues and structures belonging to two sporophytic generations and the intervening gametophytic phase." By a somewhat vague and imperfect analogy the seed might be compared with the "household" in human society. Like the average household it comprises organisms linked by consanguinity and consecutive in development.

Thus defined, seeds may be classified into the following groups, the significance of which is essentially phylogenetic.

I. GENERAL CLASSIFICATION.

Seeds facultative. Example, Selaginella.	A. Pseudosperms.
Seeds obligatory.	B. Eusperms.
1. Embryos monomorphous.	
a. Pteridophytic seeds. Example, Lepidostrobus.	I. Pteridosperms.
b. Archespermic seeds.	II. Archesperms.
2. Embryos dimorphous.	
a. Metaspermic seeds.	III. Metasperms.

In the above it will be observed that the basis for the separation of seeds into the two fundamental groups is determined by their appearance as (1) unnecessary or (2) necessary aggregates in the life of the species. In by far the great majority of seed-bearing plants seeds are characteristic and are normally developed as such. In Selaginella certain megasporangia have been observed to remain for a long time indehiscent, and in this condition, their spores having germinated, and the eggs having been fecundated, to assume the character of seeds. This is, however, not the rule in the genus but the exception, hence such seeds have here been named facultative seeds or Pseudosperms, to distinguish them from the obligatory seeds or Eusperms of plants in which indehiscence of the megasporangium has become the rule, and the seed is thus fixed as a normal unit in the life-history.

It will also be observed in the limitations of the classes of Eusperms that the double fecundation of Nawaschin and Guignard is accepted as a true fecundation. This position is capable of defense, but even if later proved untenable the two classes of Archesperms and Metasperms are sufficiently distinct to justify the nomenclature.

II. STRUCTURAL CLASSIFICATION.

Seeds integrated with placenta. (Inseminées of Van Tieghem,[1] *e. g.*, Loranthaceae.)	A. Synsperms.
Seed integrated separately from placenta. (Seminées of Van Tieghem.)	B. Aposperms.

Under the head of structural classification should be mentioned also the division of seeds into monocotyledonous and dicotyledonous according to the character of the embryo, into albuminous and exalbuminous, according to the persistence of the endosperm, into ategminées, unitegminées, and bitegminées (Van Tieghem), according to the presence and number of the integuments, etc., but these classes are after all of comparatively secondary importance. They do not bring into view fundamental differences between seeds, but only incidental. For example, the difference between the monocotyledonous and the dicotyledenous embryo is probably by no means of fundamental importance, but represents different adaptations of haustorial organs during intraseminal life; the difference between albuminous and exalbuminous seeds arises through nutritive adaptations between embryo and endosperm and is of secondary importance; the difference between seeds with one or two integuments is after all a question of indusial development and need not be given great weight. It is true that these distinctions are of great value to the taxonomist and enable him to classify plants to advantage. Yet in comparison with the distinctions brought out below they are probably less significant in the specific life.

[1] The classification of flowering plants constructed by Van Tieghem principally upon the basis of seed structure contains much of interest. Unfortunately it is not natural, the characters taken for primitive being in many instances either vestigial or derived. Thus it results in an inversion of relationships. This is well illustrated by the position given to such a family as the Loranthaceae. On account of the high ecological specialism of the plants herein included degenerate structures would be certain to appear. It is precisely these that Van Tieghem accepts as primitive. This fact in itself is perhaps a sufficient commentary on the taxonomic value of the Van Tieghem sequences.

III. GENETIC CLASSIFICATION OF METASPERMS.

A. Seeds with parthenogenetic embryos.

A. Parthenosperm.

I. Both embryo and endosperm parthenogenetic.

I. Euparthenosperm (1)

II. One plant, either embryo or endosperm, not parthenogenetic.

II. Hemiparthenosperm

a. Endosperm result of fecundation, embryo parthenogenetic

a. Parthenembryosperm

1. Effective pollen arising in same flower with seed.

1. Autembryosperm (2)

2. Effective pollen arising in neighboring flower on same stock.

2. Geitonembryosperm (3)

3. Effective pollen arising in flower of another stock.

3. Xenembryosperm (4)

4. Effective pollen arising upon stock of another species or variety.

4. Bastardembryosperm (5)

b. Embryo the result of fecundation, endosperm parthenogenetic.

b. Parthenendosperm

1. Effective pollen arising in same flower with seed.

1. Autendosperm (6)

2. Effective pollen arising in neighboring flower on same stock.

2. Geitonendosperm (7)

3. Effective pollen arising in flower of another stock.

3. Xenendosperm (8)

4. Effective pollen arising upon stock of another species.

4. Bastardendosperm (9)

B. Seeds with nc parthenogetic embryos.

B. Gamosperm

a. Embryos arising through autogamy.

a. Autosperm (10)

b. Embryos arising through allogamy.

b. Allosperm

1. Embryos arising through geitonogamy.

1. Geitonosperm (11)

2. Embryos arising through xenogamy.

2. Xenosperm (12)

c. Embryos hybrid.

c. Bastardosperm (13)

The figures 1–13 following the names designate fundamental seed types all of which theoretically might arise upon a single plant. Naturally, however, seeds of one or two types will be produced in abundance by the individuals of a species, while others will be extremely

rare. In the genus Viola, for example, plants with cleistogamous flowers will normally produce both autosperms and xenosperms. In Polygala, species exist capable, from the ecological relations of their flowers, of producing a greater variety of seeds. These would differ essentially in their manner of development, while resembling each other structurally to such a degree that they would be indistinguishable by any of the ordinary tests. Furthermore, it may very well be that the xenosperm borne on a stock which is itself the development from a xenosperm will differ intrinsically from the xenosperm which is borne upon a geitonospermous or autospermous stock. Thus a new element of complexity is brought in and an explanation is perhaps afforded of so-called "sports" or mutations. Here also may be an explanation of certain genera which include large numbers of closely related "species." May it not be possible that in a species there will be distinctive xenosperm, autosperm, geitonosperm, and parthenosperm varieties, the continual production of which gives an appearance of *related species* rather than of special seed varieties? For example, would this explain Crataegus, Rubus, and Hieracium? And may not the mutation forms of De Vries be plants which have arisen from rare and unusual seed-types, developed, however, in accordance with the laws of plant reproduction?

In any event the consideration of the regular causes that underlie the observed individuality of seeds may lead to useful results in plant-breeding. It seems very certain that to regard seeds as necessarily equivalent because borne upon the same stock is a grave and positive error. They may even pass all the ordinary tests and yet be extremely unlike, so much so that they will upon development give rise to plants so different that they may rightly be classed as different species. Returning to the analogy mentioned above, it would seem as if there were no more reason to deny individuality to the seeds borne in a head of grain, upon *prima facie* evidence, than there would be to deny the individual character of each household in a city. —CONWAY MACMILLAN, *University of Minnesota.*

THE SENSITIVE PLANT AS A WEED IN THE TROPICS.

(WITH ONE FIGURE)

EVERYONE who has traveled much in the tropics knows that *Mimosa pudica* is a weed which gives considerable trouble to the

planters, but so far as I am aware no photographs of the way it luxuriates have been published. It may be interesting to those who have not seen the plant in its own home to look at a photographic reproduction of a large patch of it which I observed recently in Ceylon.

I was returning from Peradeniya to Colombo and the train stopped for a few minutes at a way station in the lowlands, an hour's ride from the city, just long enough, in fact, to allow me to get a snap-shot

Mimosa pudica, as it grows luxuriantly in Ceylon.

of a field quite disfigured by Mimosa. The cattle pastured in the field had eaten the herbage closely around the plant, leaving it strictly alone, and as it crept across the meadow it killed out all other plants, forming a dense deep patch of spiny, creeping stems and delicate pink blossoms, which resembled miniature dandelion or thistle heads gone to seed.

The leaves were all expanded horizontally as I approached, but when my feet shook the soft earth, like a hermit crab draws into its shell, or a coral pulls in its tentacles, the plants, in the radius of the shaken ground, quickly folded their leaflets together and dropped their leaves into the characteristic position of rest which everyone knows who has seen the living plant.

To one acquainted only with the delicate specimens in European and American greenhouses, the novelty of walking over such beds of

it in the tropics does not soon wear off. I have been on railway lines whose embankments were covered with Mimosa, and watched with keen amusement, as the train advanced, the quick falling of the leaves like the progress of a roller on the seacoast.

In Ceylon the planters complain that it is among their most troublesome weeds, and one sees it everywhere in the cocoanut groves and tea plantations. Though highly interesting and valuable in a botanical laboratory, *Mimosa pudica* is quite useless on a tropical estate.— DAVID G. FAIRCHILD, *U. S. Department of Agriculture.*

CURRENT LITERATURE.

MINOR NOTICES.

THE TENTH PART of Wiesner's *Die Rohstoffe des Pflanzenreiches*[1] concludes the twenty-first section (641–684) on *Bluthen und Bluthentheile*, contains the twenty-second section (685–781) on *Samen*, and begins the twenty-third section on *Früchte*.—J. M. C.

"THE MOSSES OF ALASKA"[2] is the title of the 29th paper from the Harriman Alaska Expedition, and J. Cardot and I. Theriot are the authors. Not only are the mosses collected by the Harriman Expedition of 1899 included, but also species previously reported from the region. The whole number enumerated is 280, of which 124 are new to Alaska, and 46 new to science. The 26 new species are distributed among the following genera: Cynodontium, Dicranum, Trichostomum (2), Barbula (4), Rhacomitrium, Ulota, Orthotrichum, Entosthodon, Webera, Bryum (8), Polytrichum, Brachythecium, Plagiothecium, and Hypnum (2).—J. M. C.

IN A STUDY of the conditions influencing the germination of the spores of *Agaricus campestris*, Miss Margaret C. Ferguson[3] has found "that if a few spores are able to germinate under the cultural conditions, or if a bit of the mycelium of *A. campestris* be introduced into the culture, the growth resulting will in either case cause or make possible the germination of nearly all the spores of the culture, provided, of course, that the other conditions are not such as to inhibit germination." Cultures in various substances and under different conditions showed much variation in germination but no very constant results. The article is accompanied by three plates, illustrating the growth of *A. campestris* and culture methods employed.—R. E. SMITH.

THE THIRTEENTH (1902) report of the Missouri Botanical Garden consists chiefly of a paper by Dr. Trelease, entitled "The Yucceae" (pp. 27–133, *pls. 100*). The four genera are *Hesperaloe*, with two species; *Hesperoyucca*, regarded as a monotypic genus; *Clistoyucca*, a subgenus of Engelmann's raised to generic rank and containing one species; *Yucca*, with

[1] WIESNER, JULIUS, Die Rohstoffe des Pflanzenreiches, etc. Volume II, pp. 641–800. *figs. 200–248*. Leipzig: Wilhelm Engelmann. 1902. *M* 5.

[2] Proc. Wash. Acad. Sci. **4**: 293–372. *pls. 13–23*. 1902.

[3] A preliminary study of the germination of the spores of *Agaricus campestris* and other basidiomycetous fungi. Bull. 16. Bureau Plant Industry, U. S. Dept. of Agric. pp. 43. *pls. 1–3*. 1902.

twenty-eight species, six of which are new; and *Samuela*, a new genus comprising two species. Detailed synonymy, descriptions of numerous varieties, and full discussions of relationships are presented. The plates for the most part are reproductions of excellent photographs, showing habit and certain details; three plates are devoted to seeds, and twelve to geographic distribution.—J. M. C.

VERSCHAFFELT[4] has studied the occurrence of hydrocyanic acid in developing shoots of *Prunus Padus* and *P. Laurocerasus*, with the following results: As the buds open and the shoot develops, the HCN-compounds increase in amount as rapidly as do the other substances, so that the percentage amount of these compounds changes very little. It seems that these hydrocyanic bodies appear independently of light, and that they are not derived from the internode below the growing bud. In what form the hydrocyanic acid occurs is not yet determined. That maceration is necessary before complete distillation of the acid can occur would seem to indicate the presence of some compounds which can be split by an enzyme. The marked occurrence of benzaldehyde in the distillate from the developing buds makes it probable that glucosides related to amygdalin are present.—B. E. LIVINGSTON.

A RECENT BULLETIN of the U. S. Department of Agriculture, Bureau of Soils, contains three valuable papers by Briggs and Lapham[5] on soil physics. Following are some of the conclusions: (1) dissolved salts in general do not increase the capillary rise of soil waters; (2) concentrated solutions of all salts materially decrease capillary activity, but this effect is less marked with sodium carbonate than with natural salts; (3) the capillary rise of water in moist soil is much greater than in soil which was air-dry at the beginning of the experiment; thus for sea-island soil it was found that the maximum rise in dry soil was 37^{cm}, while the limiting value of capillary movement in moist soil was not less than 165^{cm}; (4) suspended clay may be advantageously separated from soil solutions by means of a porous clay filter tube and a compressing air pump, the solution being forced through the filter by increased air pressure.—B. E. LIVINGSTON.

A NEW SERIAL PUBLICATION has appeared, entitled *University of California Publications, Botany*, and intended to be a series of original papers in botany. Each volume will contain about 350 or 400 pages, and the subscription price is $3.50, the papers comprising those on general botany and West Coast botany. Professor W. A. Setchell is the editor of the series.

[4] VERSCHAFFELT, E., On the prussic acid in the opening buds of Prunus. Koninkl. Akad. van Wetenoch. te Amsterdam. 31–41. (Je 25) 1902.

[5] BRIGGS, L. J. and LAPHAM, M. H., Capillary studies and filtration of clay from soil solutions. Bull. 19. Bureau of Soils, U. S. Dept. of Agric. 1902.

The first number is a paper by Harvey Monroe Hall,[6] entitled "A botanical survey of San Jacinto mountain". The general features of the mountain as to position, topography, soil, climate, and geology are given. This is followed by an account of the plant distribution, both on the basis of life zones and phytogeographic formations. The latter are presented as chaparral, forests, undergrowth, meadows, riparian formation, pond formation, and crest formation. The factors affecting plant distribution are discussed under the heads of altitude, temperature, moisture, slope exposure, desert winds, rock surface, avalanches, land slides, and water courses. The flora is said to be composed of distinct boreal and austral elements, with an admixture of certain Arizonan and New Mexican species. A catalogue of the species collected in or above the yellow pine belt includes 9 gymnosperms, 78 monocotyledons, and 365 dictotyledons. New species are described in Elymus, Stipa, Oxytheca, Potentilla (2), and Erigeron.—J. M. C.

F. HEYDRICH[7] has presented a novel theory as to the homology of the tetrasporangium in the Rhodophyceae. This structure he regards as the predecessor of the cystocarp and hence a true sporophyte. The idea is at least a suggestive one, but its establishment would require a far more careful and thorough investigation than the author apparently has made. He bases his work on Oltmann's studies, where it has been shown that the fertilized nucleus of the carpogonium passes out into the auxiliary cell and there by division gives rise to the spores. This nucleus, however, never undergoes a secondary fusion with the auxiliary nucleus. Heydrich finds that two cells are concerned with the production of the tetrasporangium. These cells arise from a pericentral cell of a branch, homologous with the cell and branch from which the procarp arises. The nucleus of the cell nearest the parent branch, the stalk cell, he considers as the fertile energid. This nucleus now divides, one daughter nucleus remaining in the stalk cell, the other passing to the distal cell, which is now the tetrasporangium mother cell. No nuclear fusion takes place, but instead the original nucleus breaks down, possibly contributing somewhat in the way of food to the immigrant. The spores all arise from the entering nucleus. This is a striking parallel with the behavior of the fertilized nucleus of the carpogonium as reported by Oltmann and others.

The examination embraces quite a wide range of forms, including representatives of both the zonate and tripartite types of division, in all of which these conditions are true. Lack of detail in the figures, brief treatment of many important stages, homologizing structures, in some cases on external appearance alone, together with dogmatic statements as to the kinship of nuclei when no mitotic figures are shown, fail to carry the conviction that this

[6] Univ. Calif. Publ. Bot. **1**: 1–140. *pls. 1–14.* 1902.

[7] Das Tetrasporangium der Florideen ein Vorläufer der sexuellen Fortpflanzung. Bibliotheca Botanica 57.

theory is to be regarded as firmly established on fact. However, it deserves investigation.—J. J. WOLFE.

THE MITOSES in the megaspore mother cell of several liliaceous forms, especially *Galtonia candicans*, *Scilla sibirica*, and *Tulipa Gesneriana*, are described in great detail in a paper by Schniewind-Thies.[8] In Galtonia the mother cell usually gives rise to a row of four potential megaspores, but occasionally only two cells appear in the row, one of which may germinate directly to form the embryo sac, a transition between the condition in Lilium, where the megaspore mother cell develops directly into the embryo sac, and the condition where one of four megaspores produces the sac. In any case, the first mitosis in the megaspore mother cell shows the reduced number of chromosomes. The second division in a form like Lilium corresponds in all essential details with the second division in a form which is to have two or four megaspores, and there is a similar correspondence in the third divisions. In Scilla it is interesting to note that while the number of chromosomes in the gametophyte is eight, the number in the sporophyte varies from eight to sixteen. In Tulipa, at the first mitosis in the mother cell, each of the daughter nuclei contains twelve chromosomes, and in the two succeeding mitoses this number is maintained at the micropylar end of the sac; but at the chalazal end the sporophyte number may appear at the second division, or the number may vary, fifteen, sixteen, and twenty-one having been counted. The writer believes that the new generation begins with the reduction division, both in the embryo sac mother cell and in the pollen mother cell, and he has no doubt that the processes in the ovule and in the microsporangium of angiosperms are homologous. The four potential megaspores correspond to the four microspores (pollen grains); cases of two potential megaspores show a step toward the further reduction which is found in forms like Lilium. The fact that the megaspores take the form of a row is due to position, there being no opportunity for early isolation and rounding off as in microsporangia.—CHARLES J. CHAMBERLAIN.

NOTES FOR STUDENTS.

FRANCIS E. LLOYD[9] has described vivipary in *Podocarpus Makoyi*. The embryo develops continuously, the hypocotyl passing out through the micropyle while the seed is still attached. The phenomenon is said to be well known in Japan, but does not seem to have been recorded in English.—J. M. C.

[8] Die Reduction der Chromosomenzahl und die ihr folgenden Kerntheilungen in den Embryosackmutterzellen der Angiospermen. 8vo. pp. 34. *pls. 5*. Jena: Gustav Fischer. 1901.

[9] Rhodora **2**: 113–117. *figs. 3*. 1902.

F. PÉCHOUTRE[10] has made an extended study of the development of the ovule and seed of the Rosaceae. He describes in detail the formation of the ovular protuberance and the integuments. He finds remarkable uniformity in the development of the sporogenous tissue, a large number of species, representing all regions of the family, showing the many-celled archesporium and general characters of the classic *Rosa livida*. The early stages in the development of the embryo were studied in numerous forms, special stress being laid upon the various phases of the suspensor. All gradations are shown from the small, more or less elongated filamentous form to the short and compact massive type.—J. M. C.

IN LIEFERUNG 213 of Engler and Prantl's *Natürlichen Pflanzenfamilien*, Potonié discusses the Cycadofilices. He notes that this alliance, originally set up in his *Pflanzenpalaeontologie* (1898), has been adopted by Dr. Scott in his *Studies in Fossil Botany*, and by Mr. Seward in the arrangement of the vegetable fossils in the British Museum. Anatomical characteristics make it very probable that the forms included under the heading Cycadofilices are intermediate between the ferns and gymnosperms, although practically nothing is yet known of their reproductive organs. The illustrations, where they are not original, are largely reproductions of the admirably clear figures in Dr. Scott's recent text-book of palaeobotany.—E. C. JEFFREY.

M. L. LUTZ[11] shows by cultures that certain algae and fungi are able to absorb and apparently to assimilate amides without first breaking them down into ammonium salts. His experiments were performed upon *Pleurococcus miniatus* and *Raphidium polymorphum* for algae, and upon *Pencillium glaucum* for fungi. A number of amides were tested. The results are in general in accord with those of Czapek[12] in the same field, a fact to which the author calls attention in a note. The only point of disagreement between the two series of cultures independently made by these two authors is in regard to the effect of butyramide upon Aspergillus. Czapek failed to obtain growth in this substance; while Lutz records an excellent development therein.—B. E. LIVINGSTON.

THE EFFECT of dissolved oxygen and carbon dioxid upon the development of plankton has been investigated by Whipple and Parker.[13] The phys-

[10] Contribution a l'étude du developpement l'ovule et de la graine des Rosacées. Ann. Sci. Nat. Bot. VIII. **16**: 1–158. *figs. 166.* 1902.

[11] Recherches sur la nutrition des Thallophytes a l'aide des amides. Bull. Soc Bot. France **48**: 325–334. 1902.

[12] Zur Kenntniss der Stickstoffversorgung und Eiweissbildung bei *Aspergillus niger*. Ber. Deut. Bot. Gesells. 130–139. 1901. Also, Untersuchungen über die Stickstoffgeweimung und Eiweissbildung der Pflanzen. Hofmeister's Beiträge **1**: 538–560. 1902.

[13] WHIPPLE, G. C. and PARKER, H. N., On the amount of oxygen and carbonic acid dissolved in natural waters and the effect of these gases upon the occurrence of microscopic organisms. Trans. Amer. Micr. Soc. **23**: 103–144. *pls. 19–22.* 1901.

ical principles underlying solution of these gases and the methods best adapted to their determination in natural waters are quite fully treated. Ordinarily both carbon dioxid and oxygen are necessary for the life of the micro-organisms in natural waters. Consideration of the relative amounts of these gases is shown to be of great value in explaining certain problems of vertical and seasonal distribution. What seems to be a causal relation is pointed out between the great carbon dioxid content of ground waters and their peculiar tendency to support diatom growth. Interesting curves and tables accompany the paper.—B. E. LIVINGSTON.

JOHN CUTLER TORREY,[14] in studying the "Cytological changes accompanying the secretion of diastase," concludes that among the grasses "diastase of secretion" arises in the nucleus of the epidermal cells of the scutellum; that zymogenesis begins in the nuclei before the advent of the resting period; that at some time during the first and third days of germination the diastase-secreting cells swell to three or four times their original size; that during the first and third days there are "waves" of secretion, so that this process may be described as intermittent, but from that time on, until final exhaustion of the cells, the secretion is more continuous; that the secreting cells begin to degenerate about the tenth day; that it is highly probable that the chromatin takes an active part in the zymogenesis; that the nucleus is in this case very clearly the metabolic center of the cell; and that there is a marked difference in secretory processes in plants and animals.—J. M. C.

L. COCKAYNE[15] continues the account of his studies of the seedlings of New Zealand and Chatham island plants. He finds that many species common to New Zealand and Chatham islands are similar in their young stages, but become different in their adult forms, the New Zealand forms becoming strongly xerophilous in structure, while those from Chatham island retain their juvenile characters. A number of New Zealand species pass through three distinct stages in their individual development: first the juvenile form, then this gives place to an extremely xerophilous form, and finally this is replaced by a form which resembles the first. Similar forms from Chatham island do not pass through the xerophilous stage, and the New Zealand plants when grown under favorable conditions of moisture omit this stage also, resembling the juvenile form throughout. The author considers the bearing of these facts on the relationships and history of the flora of these two regions.—W. B. MCCALLUM.

VALUABLE DETERMINATIONS of the constituents of the fruit of the cocoanut (*Cocos nucifera*) are given by J. E. Kirkwood and W. J. Gies.[16] The milk

[14] Bull. Torr. Bot. Club **29**: 421–435. 1902.

[15] An inquiry into the seedling forms of New Zealand phanerogams and their development. Trans. New Zealand Inst. **33**: 265–299. *pls. 10–12.* 1900.

[16] Chemical studies of the cocoanut with some notes on the changes during germination. Contrib. N. Y. Bot. Garden no. 26. Bull. Torr. Bot. Club **20**: 321–359. *pl. 19. figs. 1–6.* 1902.

of the green nut is an aqueous solution containing large proportions of a reducing sugar (probably a mixture of dextrose and galactose) and some cane sugar, together with much hydrochloric and phosphoric acid in combination with both alkaline and earthy bases. There is very little proteid in either milk or endosperm. In the mature nut the milk contains little monosaccharide and much cane sugar. The mature endosperm contains much fat and insoluble carbohydrate material The fat is mainly glycerides of caprylic, lauric, myristic, and palmitic acids. Besides cellulose, a polysaccharide gum is present in considerable quantity, and several sugars, but these only in small amount. The proteid present is largely edestin. A diastatic enzyme and oxydase occur in both milk and endosperm, but no appreciable quantities of any protoelytic or adipolytic enzyme were found.— B. E. LIVINGSTON.

MISS ETHEL SARGANT[17] has long been studying the vascular system in monocotyledonous seedlings, and has reached the conclusion that the symmetry and structure of the vascular system of the seedling can be used as a guide to the phylogeny of the Liliaceae. She regards the genus Anemarrhena as a primitive type in the family, two opposed collateral bundles occurring in the cotyledon. This is taken to represent the "bicotyledonary" system of a remote ancestor. In other words, the monocotyledons are specialized, reduced forms of dicotyledons, in which two separate cotyledons have gradually united. It will be recalled that Mr. H. L. Lyon[18] has suggested on the other hand, that the dicotyledonous condition has been derived from the gradual splitting of the single cotyledon of monocotyledons. Miss Sargant calls attention to the fact that among monocotyledons the apex of the cotyledon often remains within the endosperm, a habit that "would naturally lead in course of time to the fusion of the cotyledons within the seed." In a later number of the same journal[19] Mr. A. G. Tansley objects to this "reduction" theory.—J. M. C.

GEORGE JAMES PEIRCE[20] has studied "The root-tubercles of bur clover (*Medicago denticulata* Willd.) and of some other leguminous plants." His conclusions are that though the bacteria that form the tubercles are usually only slowly motile in artificial cultures, this proves nothing as to their motility in the soil: that the proportion of root hairs affected is very small; that infection of the roots may be resisted by cutting off the infected ends of the root hairs; that the bacteria enter a root hair by softening or dissolving a small portion of the wall and moving or growing through this; that the infection thread is chemotropically attracted to the layer of cells next the central cylinder; that the tubercules originate only endogenously and from the same

[17] The origin of the seed-leaf in Monocotyledons. New Phytol. 1: 107–113. 1902.

[18] Minn. Bot. Studies 643–655. 1901. [19] New. Phytol. 1: 131–133. 1902.

[20] Proc. Calif. Acad. Sci. III. Bot. 2: 295–328. *pl. 29.* 1902.

layer that gives rise to lateral roots, and hence are morphologically lateral roots; that tubercles are largest and most numerous near the surface of the soil; that the presence of bacteria prevents the infected cells from forming starch grains; that the bacteria cause the degeneration and almost complete destruction of the nuclei; that infected cells soon lose the power of division, though not of growth; that the relation of the bacteria to their host-cells is parasitism; that it is difficult to understand how the plant as a whole can profit by an association which injures and finally destroys the cells.—J. M. C.

LUIGI BUSCALIONI,[21] in an extensive preliminary notice, describes his studies on the development of the root in the monocotyledons. His results are new and interesting in many respects; and their early publication *in extenso* is to be desired. The author calls attention to the fact that in the root of the same species the periblem and plerome may originate from a common meristem, or have distinct and separate initials according as the root is of larger or smaller size. The medulla in the case of large roots often shows its community of origin with the cortex by the presence of raphide cells such as are characteristic only of the extrastelar fundamental tissues. The apparent medulla, which is often present in smaller roots, the author does not consider to be a true medulla, and designates it *medulliform tissue*. These results are of great interest from the standpoint of existing stelar hypotheses. The root would seem to be a specially favorable organ for the investigation of these problems, both on account of its primitive structure and the clear limitation of the primary meristems. Another novelty is the announcement that the origin of the tracheary elements of the root is centrifugal, in spite of the fact that the order of their lignification is centripetal. In the Dioscoreaceae and Asparagaceae, the mother cells of the tracheary elements are multinucleate. —E. C. JEFFREY.

L. GUIGNARD[22] has added certain Solanaceae to the list of plants in which "double fertilization" has been observed. His work was chiefly with *Nicotiana Tabacum* and *Datura laevis*, although enough was seen of *N. rustica*, *D. stramonium*, and *D. Tatula* to indicate that they exhibit the same phenomenon. In Nicotiana the generative cell divides in the pollen grain, while in Datura it divides after entering the pollen tube, and in both cases the male cells are small and ovoid, or very slightly elongated. In Datura a remarkable change in the form of the tube nucleus was observed to occur in the tube, a very much elongated and irregular filamentous form being assumed. In both genera the tube enters a synergid and discharges, the two male cells rapidly approaching the egg nucleus and the polar nuclei. In Nicotiana the

[21] Sull' anatomie de cilindo centrale nelle radice delle Monocotiledoni. Malpighia 15: 276–296. 1902.

[22] La double fécondation chez les Solanées. Jour. Botanique 16: 145–167. *figs.* 45. 1902.

polar nuclei do not fuse until after fertilization, while in Datura the fusion is complete before fertilization. The usual position of the polar nuclei or the fusion nucleus during fertilization is in contact with the egg. The first division of the primary endosperm nucleus is followed by a transverse wall across the sac, dividing it into two approximately equal chambers. In Datura this is followed by other transverse walls, so that the sac consists of four superposed chambers. In both genera the subsequent divisions of the endosperm cells occur in various planes and are accompanied by wall formation.—J. M. C.

ITEMS OF TAXONOMIC INTEREST are as follows: GOTTFRIED LUZE (Verhandl. Zool.-Bot. Gesells. Wien **52**: 304–305. 1902) has described a new genus (*Pseudocalea*) of Staphyleaceae from southeastern Europe.—LEROY ABRAMS (Torreya **2**: 122. 1902) has described a new Hemizonia from California.—N. L. BRITTON (*idem* 123) has described a new Hydrophyllum from Minnesota.—HENRY EGGERT (*idem* 123) has described a new Verbena from Texas.—C. L. SHEAR (Bull. Torr. Bot. Club **29**: 449–457. 1902) has described new species of Secotium, Scleroderma, Cucurbitaria, Fusicladium, Illosporium, Phragmidium, Aecidium (2), Diatrypella, Pleomassaria, Camarosporium, and Haplosporella, and has established the following new genera: *Cryptoporus* (formerly a section of Polyporus) and *Plectrothrix* (nearest to Monosporium).—E. J. DURAND (*idem* 458–465) has described new species of Discomycetes in Ciboria (2) and Sclerotinia.—F. LAMSON-SCRIBNER and E. D. MERRILL (*idem* 466–470) have described new species of Argrostis, Elymus (2), Festuca, Sitanion, and Trisetum.—ALICE EASTWOOD (*idem* 471–474. *pl. 21*) has described five new species of Nemophila from the Pacific coast.—SPENCER LEM. MOORE (Jour. Linn. Soc. Bot. **35**: 305–367. *pl. 8*. 1902), in describing numerous new African Compositae, has published a new genus (*Artemisiopsis*) of Inuloideae.—P. HENNINGS (Hedwigia **41**: 145–149. 1902), in completing his account of the Javanese fungi collected by Professor Zimmermann, has described a new genus (*Discomycopsella*) of Leptostromataceae.—J. M. C.

MISS BLANCHE GARDNER,[23] in studying cell division in root tips of *Vicia Faba*, concludes that the nucleolus plays an important part in heredity. The statement is made that "the nuclear thread dips into the nucleolus" at one or several points and continues so until the nucleolus transfers itself into the thread. After the nucleus has divided, nearly all the chromatin is passed back and forms the nucleolus again. The conclusion is reached that the nucleolus is not a nutritive center. "The nucleolus is, at least in large part, a mass of chromatin material packed together in rounded form during the resting stage, and during this stage it is the important chromatin center. During division it becomes transformed into chromosomes. The nuclear

[23] Observations on growth and cell division in the root of *Vicia Faba*. Contrib. Bot. Lab. Univ. Penn. **2**: 150–182. *pl. 3*. 1902.

thread formed in the earliest stages of division merely serves as a path along which the nucleolus passes its chromatin." The author has evidently overlooked or failed to take into consideration the chromatin-nucleoli or karyosomes, which in well stained preparations of Vicia are always visible in the resting nuclei. The fact that in some forms of mitosis the true nucleolus — or plasmosome — is at the time of division entirely cast out of the nucleus into the cytoplasm, where it degenerates, has not been taken into consideration. That the nucleolus does contribute something to the chromatin is probably true, but it is very doubtful if it plays such an important part as has been assigned it by the author. The conclusion seems to be based largely on the staining reactions of iron-haematoxylin and Bordeaux red. Most cytologists now place little reliance on staining reactions.—W. J. G. LAND.

A TURNIP ROT has been under study for some time by Professor M. C. Potter of the Durham College of Science, England, and a number of articles have been published concerning it. In a communication to the Royal Society on June 12 the parasitic activity of the disease organism, *Pseudomonas destructans*, is minutely described. By direct observation it was seen to swell the wall of a healthy cell to two and a half times its natural thickness within an hour, by action of cytase which it excretes. The swelling could be recognized almost at once upon the introduction of the germs. Almost an hour, however, was required to make evident the toxic action by which the protoplasm is killed, followed by contraction and separation from the wall. The penetration of the cell wall by the bacteria was also directly observed, the time required being about three hours. All stages of this operation were well demonstrated by fixing, paraffin imbedding, and sectioning. Differential staining, using ruthenium-red for the walls and Löwit's method for the bacteria and their flagella, brought out the fact with great clearness. The enzym secreted by the organism is incapable of acting upon the mature and old epidermis. Entrance into the plant under field conditions appears to be largely through wounds. Such an unequivocal demonstration of a bacterial disease of plants is a notable addition to our knowledge of plant pathology, and is especially interesting as it comes from across the Atlantic, where it has been, and is still, much the fashion among writers of all classes to deny that bacteria are capable of originating disease in plants. —J. C. ARTHUR.

IN A PAPER READ before the Society for Plant Morphology and Physiology, J. M. Macfarlane[24] gives an historical résumé of the progress of plant cytology. He classifies the problems of plant cytology as morphological, physiological, experimental, ecological, evolutionary, and taxonomic. He suggests that the nucleoplasm and general cytoplasm may be regarded

[24] Current problems in plant cytology. Contrib. Bot. Lab. Univ. Penn. 2: 183–204. *pl. 18.* 1902.

as the vegetative substance of the cell, the chromatin granules as the highly specialized hereditary substance, and the linin as an intermediate substance which transmits hereditary peculiarities in a slow degree from the cytoplasm to the chromatin, and that the linin is in part the bearer of hereditary qualities. He considers that undue prominence has been given to the chromatin granules as the bearers of heredity. He thinks more light would be thrown on the tropisms if the cytological changes that originate or accompany them were accurately determined. He believes that the only correct guide to the evolutionary affinities of the plant groups and the development of species within these groups is to be found in the study of the morphological details of varieties and species based on the cell as the ultimate factor; also that it will not be possible to classify on a natural plan until exact information has been obtained and recorded in terms of cell life, of structural features, such as for example pigmentation of certain areas, the upbuilding of unicellular or multicellular hairs of definite structure, or the development of thickening zones, etc. When such data have been accumulated "it will be possible to classify plants on a natural plan, instead of, as now, by selecting one or two points of resemblance—not necessarily of morphological contact—as a taxonomic basis."—W. J. G. LAND.

IN A PRELIMINARY paper concerning a series of experiments now in progress at Harvard Botanic Garden, A. B. Plowman[25] gives some interesting results. Both soil and water cultures of seedlings subjected to as near normal conditions of temperature, light, and moisture as possible, were treated with both static and kinetic charges, through a range of potential from 0.5 to 500 volts. Seeds near the anode were killed by a current of 0.003 amperes or more, while those near the cathode were little affected or even stimulated. In both water and soil cultures of seedlings the same facts were established. In case the current was allowed to act for a sufficient length of time the ill effects were produced at all points between the electrodes, but slower in the soil cultures. With a current of 0.08 amperes or less the seedlings near the cathode showed an increase in the rate of growth. A provisional theory based on the disputed ionic theory is offered in explanation. From certain facts established by experiment the conclusion is made that negative charges stimulate and positive charges paralyze the protoplasm of young seedlings. For example, a positive charge of 500 volts killed lupine seedlings, while a negative charge of similar potential actually stimulated the plants; in water cultures subjected to a weak current of electricity the root-tips turn towards the anode. The explanation for the latter is that the side of the root toward the anode is retarded in its growth by the positive ions, while the opposite side is stimulated by the bombardment of the negative

[25] Certain relations of plant growth to the ionization of the soil. Am. Jour. Sci. 14: 129–132. 1902.

ions. Since the plant body is electro-positive to the soil, the negative electrons are being discharged to the plant in its normal physiological activity and are beneficial, while the reverse condition is detrimental.— F. D. HEALD.

THE EXPERIMENTAL MORPHOLOGY of the potato tuber has been taken up again by Vöchting.[26] The French variety "Marjolin" was grown in pots in garden soil. In darkness at a temperature of 6–7° C. few roots, but numerous new shoots, are developed. The latter take the form of small tubers, and never bear the small leaves normally produced in darkness. At a temperature of 25–27° C (about the optimum for growth) both roots and shoots are produced in large numbers, and the latter all have the form of normal etiolated shoots. As the temperature is decreased below the optimum, more tubers and fewer leaf-bearing shoots are produced, and in the neighborhood of the minimum for growth all the shoots are tuberous. The temperature seems to be directly effective in this response. If new tubers have begun to form in the cold, and then the culture be transferred to the optimum temperature, tuber formation ceases and the development of leafy shoots begins, to continue while the temperature is suitable. A corresponding change from the formation of leafy shoots to that of tuberous ones follows a change of temperature in the opposite direction, but leafy shoots started in the cold continue to grow as such at low temperatures. However, they change their response to the gravity stimulus entirely; while at the higher temperature they are negatively geotropic, at the lower they become positively so. The influence of the amount of water in the soil is almost as important as that of temperature. At a temperature suitable for the production of leafy shoots a culture with little water produces only tubers. When water is added to the soil leafy shoots are developed. In cultures with dry air above the soil, the leaf-bearing shoots creep along the surface of the substratum. The author concludes they are positively hydrotropic. The partial pressure of oxygen is not effective in determining the formation of new tubers or leafy shoots. But with the partial pressure of this gas the roots fail to be provided with the usual hairs. —B. E. LIVINGSTON.

COPELAND[27] has studied the mechanism of the opening and closing movements of stomata in a large number of forms well distributed throughout the plant kingdom. Several methods were resorted to in determining the way in which the various stomata open and close, the main one being the observation of tangential sections of the leaf. Observations of cross and longitudinal sections and of the stomata *in situ* were also made use of. Unless the methods are at fault (and there seems no reason to believe that

[26] VÖCHTING, HERMANN: Ueber die Keimung der Kartoffelknollen. Bot. Zeit. 60: 87–114. *pls. 3–4.* 1902.

[27] Copeland, E. B., The mechanism of stomata. Annals of Botany 16: 327–364. *pl. 13.* 1902.

they are), it appears that active movements of stomata are much more common than we have been led to believe. And the method of opening and closing, apparently always dependent upon an osmotic change in volume of the guard cells, is as various as are the plants in which it occurs. Absorption of water with its accompanying increase in the volume of the guard cells results in so altering the shape of these cells, by bending or stretching their walls, as to open the pore between them. The mechanical types of stomata studied are illustrated by figures and are tabulated by the author in the following scheme, which is copied from his concluding paragraph. "The pore opens by

1. A change in shape, rather than by stretching the walls, in which the change is

(*a*) An increase in the depth of the guard cell, in which there is chiefly concerned the entire wall except the dorsal (Medeola, Equisetum), the inner half (Mnium), the outer half (Funaria), the dorsal half (Lycopodium), the ends (Osmunda).

(*b*) An increase in the width of the slender stoma (Sagittaria).

2. Stretching the thin dorsal wall (Amaryllis).

3. A change in shape, with or without much stretching, at the ends of the guard-cells, which forces the dorsal wall, with the passive middle part of the cell, either directly backward (Gramineae), or upward and backward (Coniferae).

4. Combinations of the types of Amaryllis and Mnium (Helleborus), and of Amaryllis and the Gramineae (Achillea)." — B. E. LIVINGSTON.

SPINDLE FORMATION in *Agave americana* has been described recently by Osterhout.[28] Considerable attention was given to technique, especially to fixing. About forty fixing agents were tested by watching their effect upon the living cell, and it was found that some of the most highly recommended solutions produced profound disturbances in the cytoplasm. For most objects fixing agents were found which produced no visible change in the living cell, as far as could be observed with a 2^{mm} oil immersion lens during the application of the reagent; but even in some such cases the material undergoes structural changes after a few hours, and the time must be shortened accordingly. Flemming's strong mixture proved to be the best in most cases; very fair results were obtained with iridium chloride, platinum chloride, palladium chloride, and Flemming's strong mixture with an excess of chromic. Material was washed from two to eight hours in running water and then dehydrated. Mixtures of absolute alcohol and bergamot oil were used for clearing. Gentian violet was used for staining kinoplasm. If the stain washes out too readily, some gentian violet should be dissolved in the absolute alcohol. From two to twenty seconds' immersion in dilute iodide iodine solution just before transferring to the absolute alcohol often gives a sharper differentiation.

[28] OSTERHOUT, W. J. V., Cell Studies. I. Spindle formation in Agave. Proc. Cal. Acad. Sci. III. **2**: 255–284. *pls. 25–28.* 1902.

The summary of Professor Osterhout's work on spindle formation in *Agave americana* is partly as follows: During early stages in the first division of the pollen mother call the spindle is enclosed in a special membrane of cytoplasmic origin, which forms a complete investment around it. The functions of the membrane appear to be comparable to those of the nuclear wall and the limiting membrane of the cytoplasm. There is no weft of fibers such as is usually described for this stage. The spindle-forming fibers are radial from the beginning, and are attached both to the nuclear and spindle walls. The second division differs radically from the first, the spindle-formation resembling, in general, that described for the spore mother cells of Equisetum.

The plates are in three colors, reproducing the effect of the safranin-gentian violet-orange stain.—CHARLES J. CHAMBERLAIN.

A PHYSIOLOGICAL STUDY OF THE ANTIPODALS has been untertaken by T. Ikeda.[29] Investigations on *Tricyrtis hirta* form the subject of the first paper and it is expected that others will follow. Besides observations on microtome sections prepared in the usual way, microchemical reactions were tested on free-hand sections from fresh materials. The archesporial cell becomes the megaspore mother cell directly without a previous division into a primary wall cell and primary sporogenous cell; the mother cell gives rise to four megaspores, of which the one nearest the chalaza is functional. In the first division of the mother cell the chromatin forms tetrads strongly resembling those of such forms as Gryllotalpa, as described by zoologists. Double fertilization was observed. The endosperm does not form a parietal layer, but the nuclei are evenly distributed throughout the sac. A considerable amount of endosperm is formed before the division of the fertilized egg, one of the figures showing twenty nuclei in a single section. The chief interest in the paper lies in the microchemical investigation. In early stages no starch is found in the ovule, but as development proceeds starch appears in the funiculus and outer integument, and the outer and inner surfaces of the inner integument become cutinized except in the micropylar region. Starch then appears in the inner integument, though not as abundantly, and dextrin can be detected in the antipodal end of the sac. Just before the fusion of the polar nuclei, dextrin is evident in the micropylar portion of the inner integument and also in the antipodals and egg apparatus, while the starch has disappeared from the inner integument and appeared in the nucellus. After fertilization, the dextrin disappears from the integument and is present only in the fertilized egg, and starch has almost entirely disappeared from the integuments and is scanty in the funiculus, but after a few divisions of the embryo starch becomes abundant in the integuments and in the endo-

[29] Studies in the physiological functions of antipodals and related phenomena of fertilization in Liliaceae. Bull. Coll. Agric. Tokyo Imp. Univ. **5**: 41–72. *pls. 3–4.* 1902.

sperm. The chalaza and conducting region have a soluble carbohydrate instead of starch. Microchemical tests, together with the cytological features of the antipodal cells and the anatomical structure of the neighboring tissues, lead to the conclusion that in Tricyrtis the antipodals are the center of absorption of raw materials, of their elaboration into the proper form, and the means of transmission of food to the proper place. The dextrin in the micropylar portion of the integument is believed to serve for the nutrition of the pollen tube, while that in the egg supplies the embryo during its early stages. The cutinization of the inner integument makes it necessary for most food material from the exterior to pass through the antipodals.—CHARLES J. CHAMBERLAIN.

OPEN LETTERS.

WEBB'S "STUDY OF SPIRAEA."

In the June number of the BOTANICAL GAZETTE there appeared a paper by Mr. J. E. Webb under the title "A morphological study of the flower and embryo of Spiraea." In looking through it I noticed that the illustrations of the sections of the flowers represented obdiplostemonous flowers with but two carpels and a simple raceme, all characters which do not agree with the true Spiraeas. It became apparent, therefore, that the paper did not deal with *Spiraea japonica* Linn. f., but with *Astilbe japonica* Gray (*Hoteia japonica* Morr. and Decne. *Spiraea japonica* Hort.), an herbaceous plant belonging to the Saxifragaceae. Unfortunately it does not happen infrequently that morphological and physiological researches are based on wrongly named plants. Of numerous similar instances I shall mention here only one I came across a few days ago in the *Botanische Zeitung* (47 : 629. 1889), where a paper by J. H. Wakker on "Bau und Dickenwachsthum von *Abrus precatorius*" is published. The figure on the plate of a flattened stem and the mention in the text of "der Gattung Phaseolus ähnliche Blätter" left little doubt that the plant under consideration was not *Abrus precatorius* but *Rhynchosia phaseoloides*, which is sometimes confounded with the former on account of the similarity of the seeds. The article was reviewed in Just's *Botanischer Jahresberichte* without the error being noticed. As also in the present case Webb's paper has been mentioned in other journals without attention being drawn to the misleading names, I thought it advisable to point out that the paper chiefly deals with Astilbe, and thus refers mainly to Saxifragaceae, and the *Spiraea japonica* there cited should be changed to *Astilbe japonica* Gray, and the *Spiraea astilboides* to *Aruncus astilboides*, while *Spiraea salicifolia*, with only one illustration, will remain as the correct name.—ALFRED REHDER, *Arnold Arboretum*.

NEWS.

THE BRYOLOGIST Hugo von Klinggraeff died April 1 at Paleschken, West Prussia.

DR. B. SCHMID, privatdocent at the University of Tübingen, died April 28.

PROFESSOR ANTONIO MORI, Director of the Botanic Gardens at Modena, died April 6.

MR. E. W. D. HOLWAY spent the month of September in the mountains of western Canada collecting fungi.

PROFESSOR DR. G. LEIMBACH, of Arnstadt, Thuringia, and publisher of the *Deutsch. Bot. Monatsschrift*, was missing from his home on June 11, and on June 13 his body was found at the foot of a cliff, from which he had evidently fallen.

THE LAST REPORT (13th) of the Missouri Botanical Garden shows that the mounted herbarium consists of 364,953 specimens, 23,942 of which are thallophytes. The library contains 36,016 books and pamphlets, and at present 1,133 serial publications are received.

MRS. WILLIAM STUART, of Purdue University, for some years assistant in botany to Dr. Arthur, and for the last year associate horticulturist in the Experiment Station of that institution, has been appointed horticulturist in the University of Vermont to succeed Professor Waugh, who goes to the Massachusetts Agricultural College.

THE UREDINEAE are to receive monographic treatment by P. and H. Sydow of Berlin. Gebrüder Borntraeger announce the early appearance of the first part of the work. It is to appear in parts over a period of three or four years, and will eventually form three volumes, each containing about 1,000 pages, with a large part of the species illustrated, and all known species included with their synonymy. The price will be about 60 marks per volume to subscribers.

M. J. C. WILLIS, Director of the Royal Botanic Gardens, Peradeniya, Ceylon, proposes to be absent from Peradeniya until March 1903, on a tour through England, the United States, Japan, etc., for the study of agricultural and botanical organizations in those countries. Letters on departmental business should be sent to the Acting Director, Mr. J. B. Carruthers at Peradeniya; private letters to the Royal Societies' Club, 63 St. James St., London,

S. W., till October 1st, and to Olga, San Juan co., Washington, U. S. A. till December 15th.

THE DIVISION OF FORESTRY EXTENSION, organized in the Bureau of Forestry on July 1, to supersede the Section of Tree Planting, is to have charge of all work that deals with the creation of forests where at present there are none. Field parties are now at work in New Hampshire, Massachusetts, New Jersey, Nebraska, Oklahoma, Arizona, Washington, and Oregon. In connection with the system of cooperation with private land owners in planting the Bureau of Forestry at the beginning of the present field season had arranged 224 planting plans in 172 localities of twenty-nine different states. The majority of these plans are for woodlots of individual land owners, but in some cases plans are being made for corporations, cities, and even states. The bureau has also established nurseries in the two forest reserves recently established in the sand-hill region of Nebraska. The principal species used at first will be jack pine, western yellow pine, white fir, and Colorado blue spruce. The bureau has also recently taken up a study of the tendencies of natural forests to extend over land devoid of forest growth. Field parties are now investigating the reproduction of white pine on pastures and abandoned lands in Massachusetts and New Hampshire; another field party is studying the same problem in Oklahoma in connection with the hard wood growth which composes the timber belts of that region; and a similar study is being made of the Prescott reserve in Arizona. The reclamation of shifting sand dunes has also been taken up as a problem by the bureau. The regions most severely affected are the dune regions of the Atlantic and Pacific coasts, the lake district region of Michigan, and the Columbia river district of Washington and Oregon. Two field parties are at work on this problem, the one investigating the dune district along the Atlantic coast and the other the Columbia river district.